GROUND WATER RESPONSE TO LARGE SCALE PUMPINC IN HANDIA TEHSIL

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
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INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

April, 1978

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THE MEMORY OF MY LATE FATHER

WHO INSPIRED ME FOR THIS WORK,

BUT COULDN'T LIVE TO SEE ITS COMPLETION;

A
N
D

MY DAUGHTERS
SHALINI & MANOGYA

A 10478 *

CERTIFICATE

Certified that the work on "GROUND WATER RESPONSE TO LARGE SCALE PUMPING IN HANDIA TEHSIL" by R.L. Singh has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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ABSTRACT

With the increase in demand for irrigation to meet the requirement of larger food production, it is necessary to utilise all the water resources of a basin and reduce the wasteful discharge of water into sea. Utilisation of surface water has been going on for quite some time and in many basins in India there is just not enough surface water to meet the demand. In such situations the other alternative source is ground-water and should be fully utilised in conjunction with whatever surface water is available in the basin. Handia Tehsil in Allahabad district comes in the doab of Ganga and Gomati rivers. There is no canal irrigation to date in this area . Large number of Minor Irrigation Works, such as masonry wells, private tube-wells and pumping sets, have been in existence for some time; in addition a large numbers of state tube-wells, have been drilled in the area since 1955.

The effect of large scale pumping from the aquifer system in a area can have detrimental effects such as: Water level may go so far below that the wells may go dry; bad quality water may enter into wells due to a large depression in piezometric surface; cost of pumping may be excessive due to gradual lowering of the water level, etc.

In order to see that such a thing does not happen in the Handia area , a detailed analysis has been made on the effect of introduction of large number of State tube-wells in the Handia Tehsil on the aquifer system. The analysis is based on a Digital model adopted for the area. The effect of introducting artificial recharge in the area is also studied.

CHAPTER I

1.1 INTRODUCTION:

India, being an agricultural country, has always endeavoured to utilise its available water potential for irrigation. The utilisation of ground water from open wells and surface water from rivers, for irrigation of crops, is ancient in origin, although the construction of major irrigation systems started in the early 19th century. In the northern part of the country, perennial flow of rivers was diverted with the help of diversion weirs, whereas in south, dams were constructed across rivers to store storm flow for utilisation of the same for irrigation.

It may be noted that irrigation plays a protective as well as a productive role in the use of other agricultural inputs and thus becomes a catalytic agent in enhancing the spread of 'green-revolution'- a symbol of agricultural development (Patel and Patel, 1971).The perennial flow of rivers not fully cope with the increasing requirements of water for irrigation, as the agriculture, in large part of the area in the State of Uttar Pradesh, was a'gamble in monsoon' due to low and uncertain rainfall and absence of other water resources. It, therefore, becomes important to search out other water resources which would be least affected by

monsoon and yet supply adequate quantity of water, whenever needed (Chowdhury , 1971). This led to tapping of ground water resources from deep aquifers for irrigating tracts, where surface irrigation could not be extended. The Indo-gangetic plain, in Northern India, has a large ground-water potential. It gets replenished by annual rainfall and is recharged year after year by perennial rivers flowing in the plains of Ganga, Yamuna, Ghagra etc. (Joglekar 1965, Bahadur and Saksena, 1976).

No organised effort in the tube-well irrigation, was made in India until 1935, when Sir Willium Stampe (1934-35 to 1937 - 38) , the then Chief Engineer, Irrigation Department, United Provinces (now Uttar Pradesh); proposed a large tube-well scheme and sought the opinion of Dr. E.M. Taylor (1936) regarding its feasibility in the area.

According to Dr. Taylor's statistical analysis, 81 % of the changes in the ground-water-table were attributed to local rainfall and 19 % to factors outside the area such as rainfall in foothills. He has further reported that the existing stability of the water table would not be materially affected by pumping out subsoil water. The water table may be lowered in years of low rainfall, but will be supplemented in years of normal and heavy rainfall (Joglekar 1965).

1.2 THE STUDY AREA:

Handia is one of the eight tehsils of district Allahabad, situated in the eastern part of the district and south-east part of Uttar Pradesh (See Fig. 1). The tehsil is located in the Survey of India Toposheet No. 63-K between, the east longitudes 82°02' and 82°20' and north latitudes 25°16' and 25°36'. The tehsil is bounded in the east by Varanasi district, in the west by tehsil Phulpur of district Allahabad, in the south by tehsil Meja and Kaschhana of the district Allahabad, and in the north by district Jaunpur. Total area of the tehsil is 77860 hectares, or 192397 acres or 300.5 Sq. miles. There are four blocks in this tehsil, namely Handia block 17408 hectares (43017 acres), Saidabad block 19688 hectares (48650 acres); Pratappur block 18211 hectares (45000 acres) and Dhanupur block 22553 hectares (55730acres). On southern boundary of the area, River Ganga flows west to east (see Fig. 1 and 2).

1.3 ACCESSIBILITY:

It can be seen from Figs. 1 and 2 that the study area is well accessible by metalled roads and railways. The National High Way No.2, the great Grand Trunk Road, which connects Allahabad to Varansi and leads to Calcutta in east and Amritsar in west, passes through the study area, and

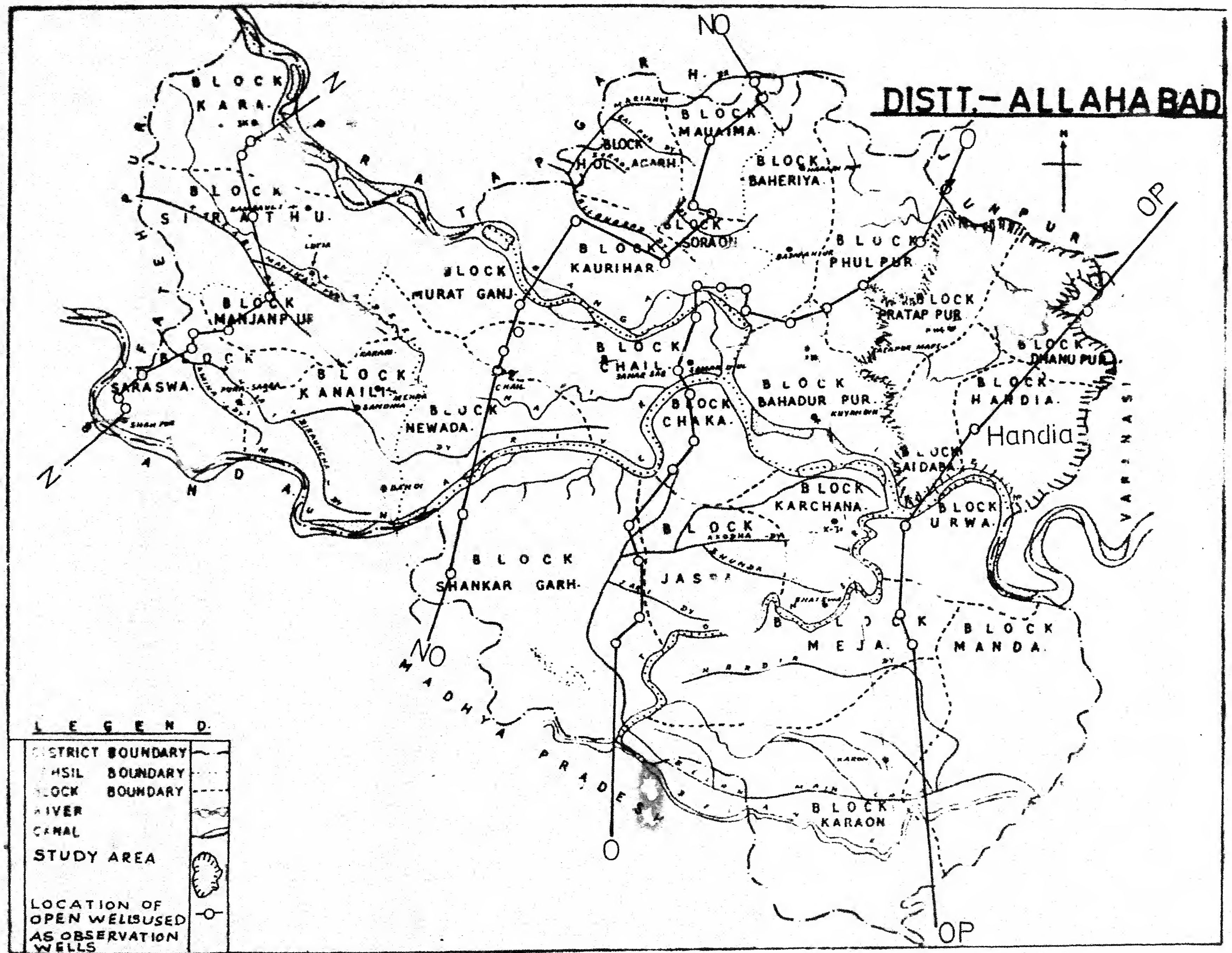


FIG.1 INDEX-MAP SHOWING STUDY AREA IN ALLAHABAD DISTRICT

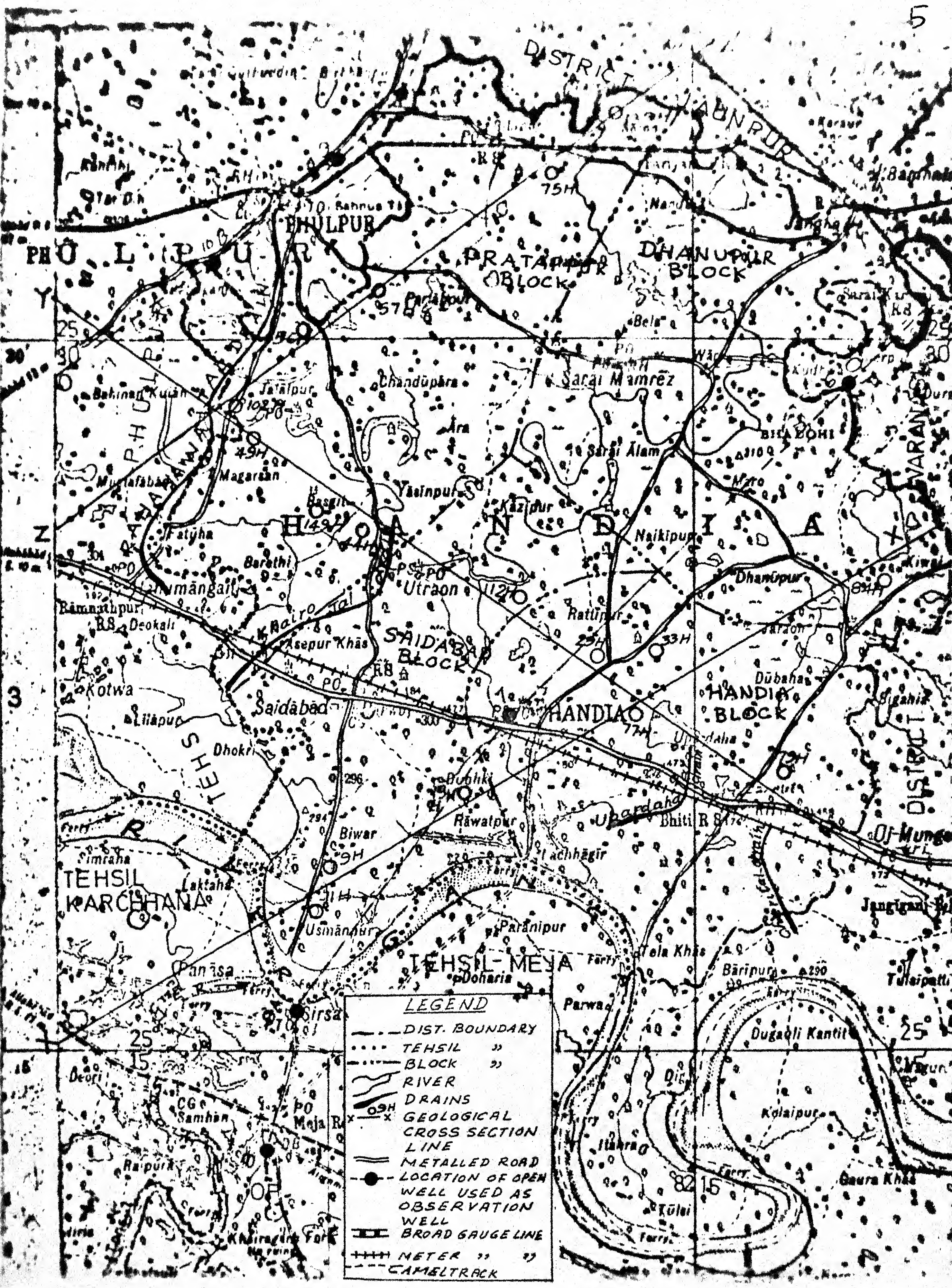


FIG.2 INDEX MAP OF HANDIA TEHSIL

divides it into two parts, approximately in the ratio of 1:4 in south and north respectively. Meter gauge line (North Eastern Railway) passes through the area, nearly parallel to the Grand Trunk Road, and connects Allahabad city (Rambagh station) to Varansi, whereas broad gauge line passes through the northern most area and connects Phulpur to Janghai and leads to Varanasi.

1.4 GEOLOGY:

According to geologists, the area of tehsil Handia is covered by Indo-Gangetic alluvium (Central Ganga alluvial plain) of quarternary age (Bahadur et.al., 1974, Pathak et.al., 1976). Along south of river Ganga , a small strip of alluvium called as marginal alluvial plain, exists between the river and the rocks belonging to Vindhyan systems (Bahadur and Saksena , 1976, Pathak et.al. ,1976). A common feature of these sediments of the alluvial plain of the area is alteration of sand and sand-gravel horizons with clay and clay-silt combinations. The sand, gravel, sandstone and loose kankar (without clay) horizons in the study area serve as aquifers (Pathak et.al. 1976, Chaturvedi , 1977, Bahadur and Saksena, 1976 , Singh et.al., 1973, Mehta, 1960).

In the geological past, pliestocene (Ice age) and recent periods , these horizons were formed by wide-spread

braided effect of the stream depositions (Jones and Hofmann, 1967). One of the typical characteristics of an alluvial river is its propensity to meander, with the result, that river Ganga which had this characteristic due to wide seasonal variations, deposited the sediment layers varying, greatly in composition and geometry (Chaturvedi, 1977). According to Jones and Hofmann, vast interfluvial flood basins are responsible for silt and clay accumulation. As such the Gangetic plains consist of large stream meander belts of medium to coarse grained sand layers of varying thicknesses and areal extent occuring at different levels within vast accumulations of silt and clay. The deep aquifers in the Gangetic plains are under confined conditions (Jones and Hofmann , 1967, Joglekar, 1965, Pathak et.al. 1976, Bisaria and Roy 1976). After inspecting strata-charts of deep wells bored in the area, it is revealed that top most layers are either loamy or silty-clay or admixture of very fine sands. Below this,there is a thick and hard layer of clay or clay mixed with kankar, which stretches throughout the area of study. In certain cases a fine sand strata intervenes this strata of hard clay or clay mixed with kankar, varying in thickness for few meters to several tens of meters below ground level. The private tube-well (P.T.W.) owners have tapped these upper aquifers generally below 30 m to 60 m. These aquifers are mostly made up of fine sand with

some patches of coarse to medium sand of brownish and greyish colours. At some places kankar and gravels are also present (see Fig. 3).

1.5 HYDRO-METEOROLOGICAL CHARACTERISTICS:

1.5.1 RAINFALL:

Indian agriculture is largely dependent on monsoons and it greatly suffers due to erratic distribution of rainfall over the year and its unpredictable behaviour. The failure of monsoon in a year or its late arrival considerably affects the economy of the area and subsequently throwing the nation's economy out of gear as it happened recently in several consecutive drought years. In the area under study, the agriculture has, therefore, been characterised still as a "Gamble in Rainfall".

As rainfall is directly related to irrigation water requirements, it was considered essential to ascertain its value for the area under-study. This was done by taking the average of the rainfalls recorded at Handia and Phulpur tehsils rain-gauge stations as former being a tehsil head quarter and later situated at western border of the study area (see Figs. 1 and 2). Fig. 4 shows the mean normal value of rainfall of these two rain-gauge stations. Fig. 5

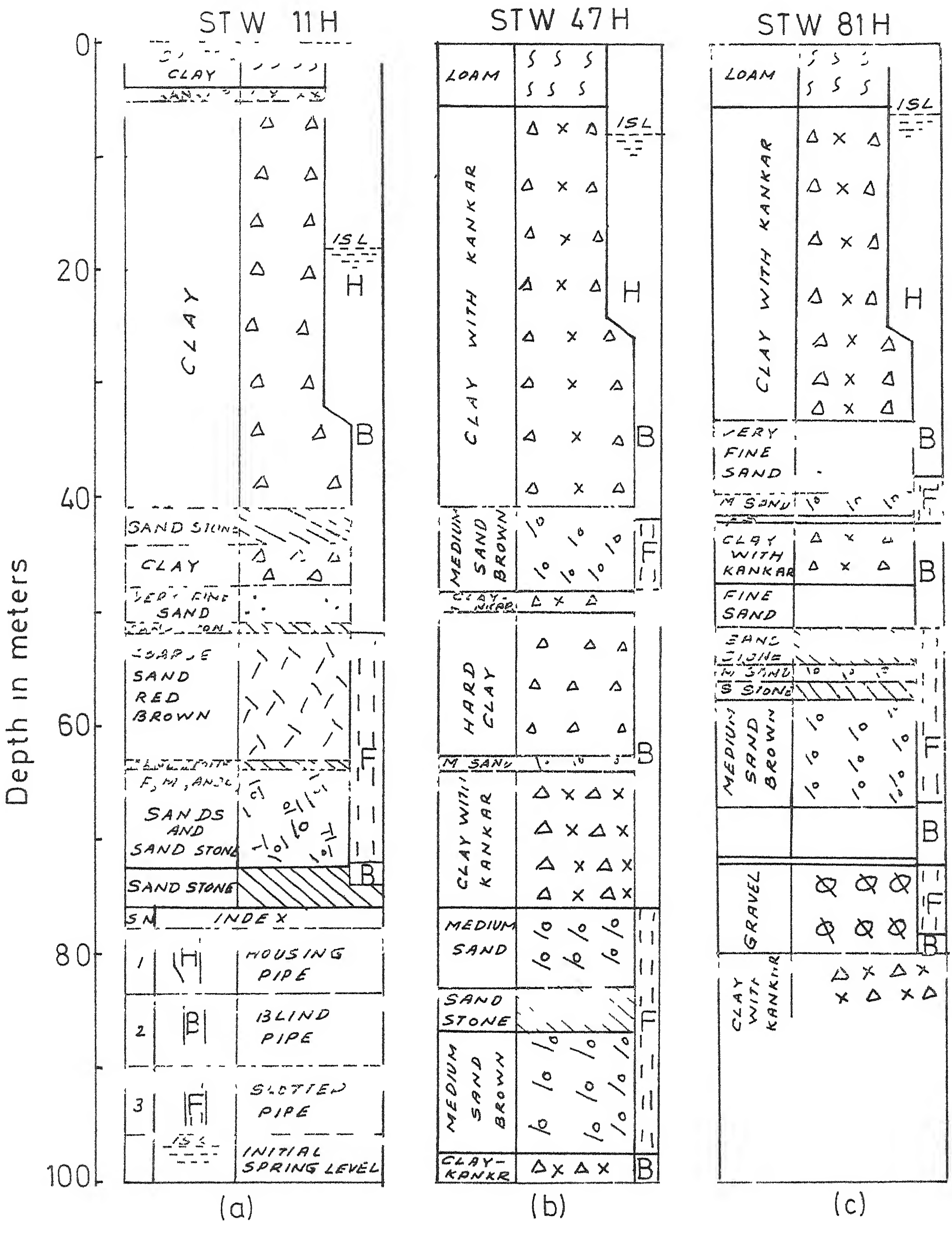


FIG 3 PIPE ASSEMBLY DETAILS WITH STRATA CHARTS

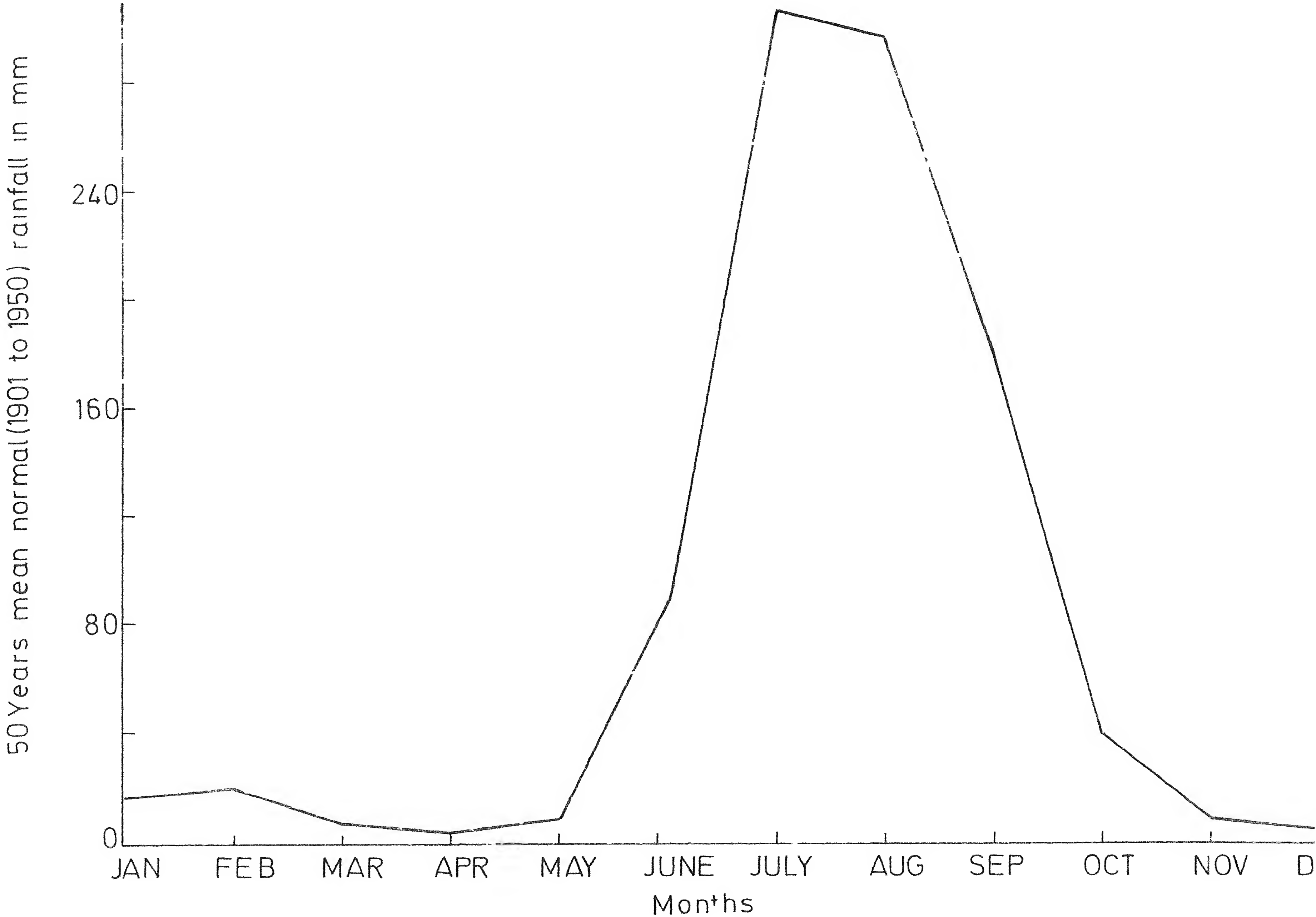


FIG 4 MEAN NORMAL RAINFALL OF HANDIA TEHSIL AREA

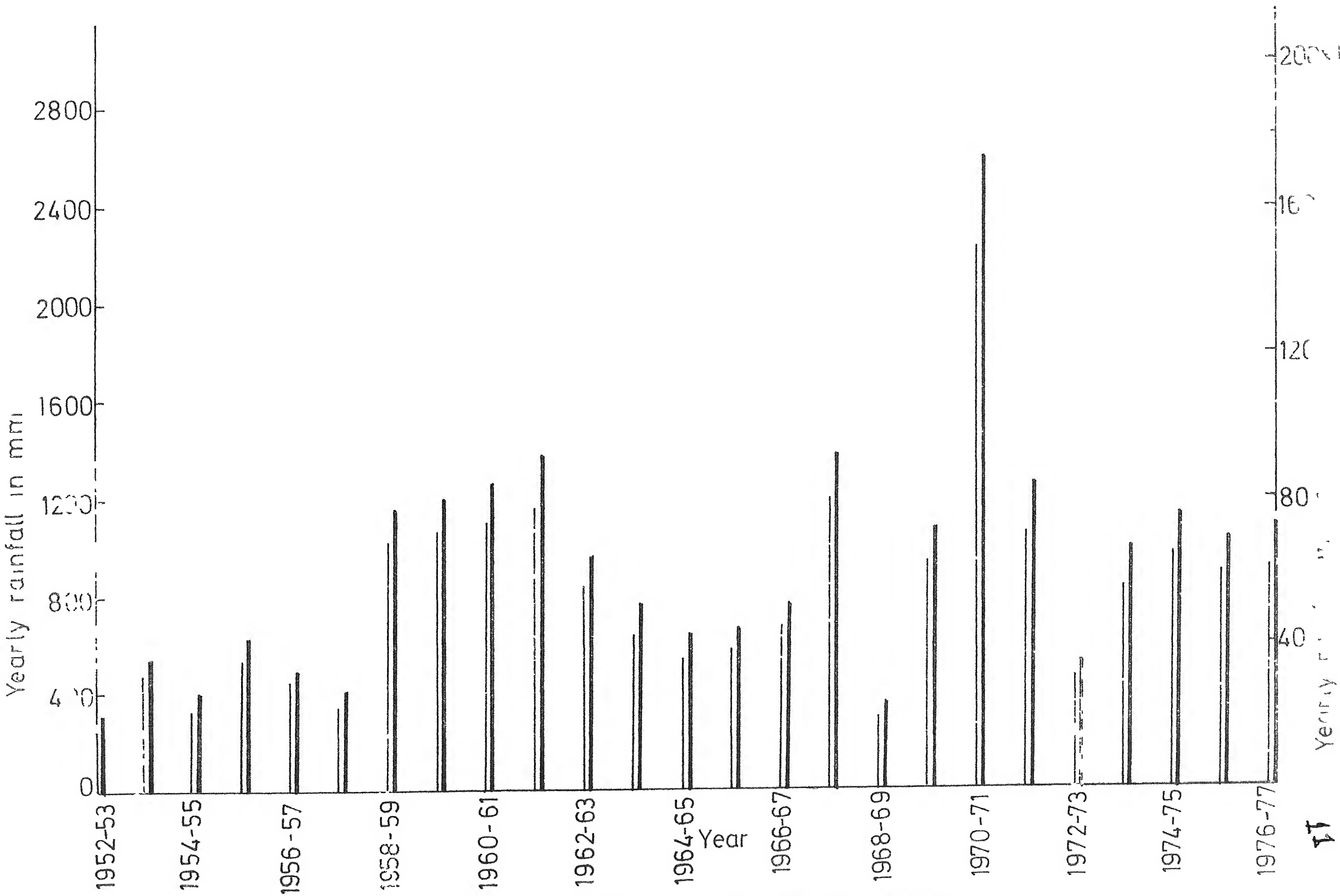


FIG. 5 YEARLY RAIN FALL IN STUDY AREA

shows yearly rainfall of the study area, based on the observations at Handia and Phulpur stations under control of Revenue Department of the State of U.P.

1.5.1.1 SEASONAL VARIATION OF RAINFALL:

It is important to note that there is a significant variation in rainfall distribution over the area during the monsoon season; equally important is the variability in the rainfall distribution over a period of time, Since the quantity of water required for irrigation is directly related to the quantity received as rainfall, variations in seasonal rainfall amounts are vital in assessing both the needs for, and, returns from irrigation. The irrigation systems becomes worthless in the year of heavy and timely rainfall, but it becomes something of extreme necessity in the year of drought. Therefore, it becomes essential to determine the water requirements for a crop and also its response to the quantity of water, in view of the varying rainfall with time over a given area. Hence study of rainfall is very essential for knowing ground water response to large scale pumping in the area.

The major portion of the rainfall in the area is by monsoon, which sets in towards the end of June and continues till October. July and August are the peak months and more than 80 % of yearly rainfall takes place

during July, August and September. Winter rains in the area are scanty and are received towards the end of December and sometimes upto the end of February. The monsoon rainfall accounts for about 85 % of the annual rainfall (Bahadur et.al. 1974, Ref. Fig. 4). Rainfall recorded at Handia rain-gauge station is generally greater than that of Phulpur. The rainfall is highly variable which often results in drought and flood conditions (see Fig. 5). (By communication).

For agricultural purposes, the annual regime of precipitation (monthly distribution through out the year) turns out to be more significant than the annual average. Critchfield (1966) has compared precipitation graphs for Allahabad (India) and Washington D.C. (U.S.A.)(See Fig.6)and has illustrated the difference in the two regimes, although these stations have approximately the same average annual rainfall, that is 1061.72 mm (41.8") and 1036.32 mm (40.8") respectively. During the rainy season the prevailing direction of wind is from the west.

1.5.2 DRAINAGE:

Ganga is the main river flowing in the southern most part of the study area. There is another river namely Burna or Varuna which takes birth in this area and drains out north eastern part of the area. As frequency and

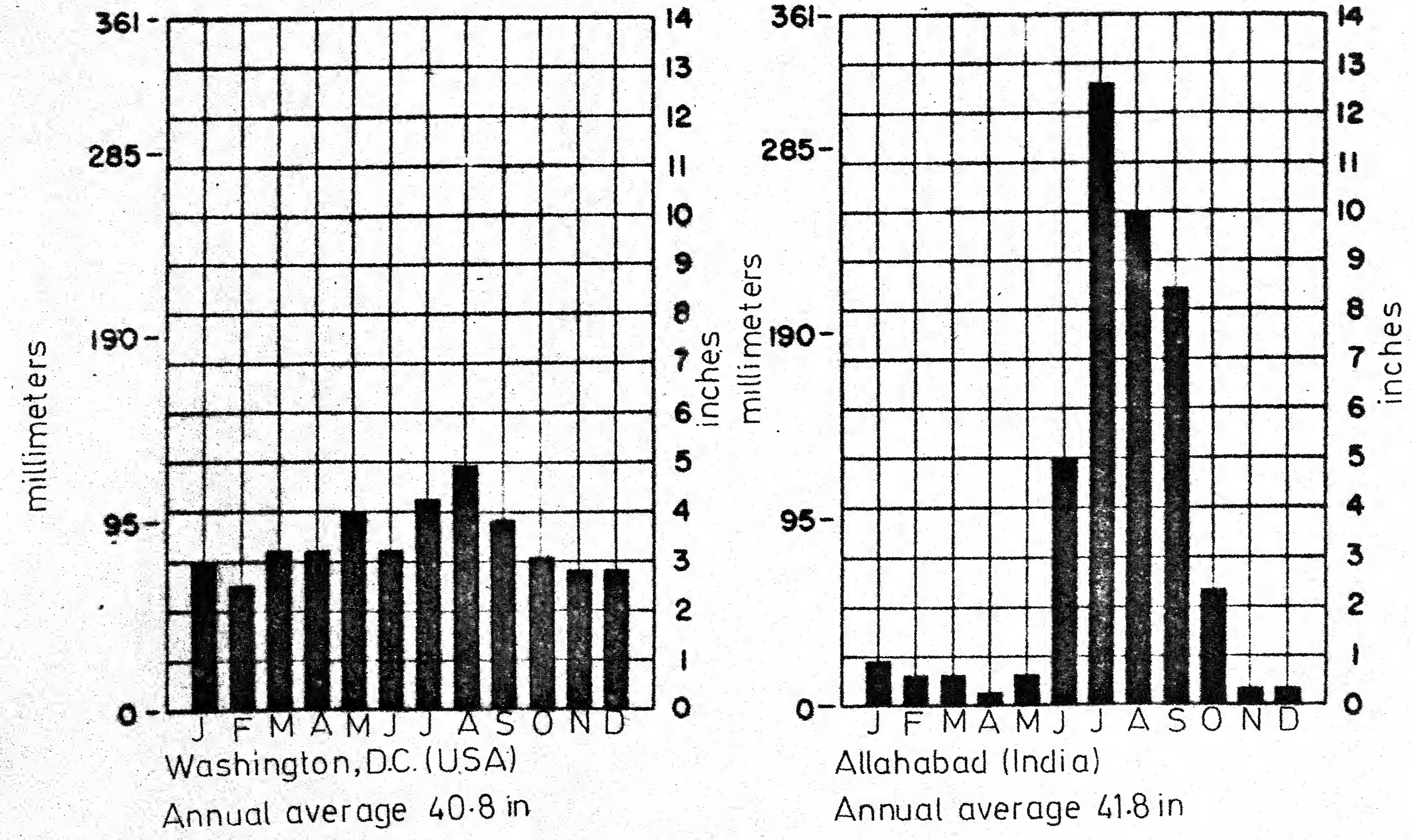


FIG.6 MONTHLY PRECIPITATION GRAPHS FOR WASHINGTON AND ALLAHABAD
(Ref. Critchfield,1966,page67)

intensity of daily rainfall in the area created surface drainage problems in past hence to take care of the excess water accumulated due to heavy rainfall during some periods of the year, four artificial drains, were constructed, which drain out water of the area into the Ganga river (Fig. 2). These drains are:

1. Cheri Tal drain
2. Upardaha Tal drain
3. Khairo Tal drain
4. Rahanawai Tal drain.

There are a few big ponds locally called as'Tals' in the area, which were dug out in the past to store water during monsoon to control flood and also to provide water for domestic use. Some of these ponds are pucca, having bathing ghats and pucca steps around its periphery.

1.5.3 CLIMATOLOGY:

1.5.3.1 TEMPERATURE AND HUMIDITY:

The entire area has humid and sub-tropical monsoonic climate. In summer it is dry and hot, while in winter it is mild and cold. Prolonged summer is followed by rainy season. Summer starts from the month of March and the temperature reaches the highest value during June, when

mercury level rises to 44°C (Bahadur et.al. 1974) and sometimes to nearly 47°C as observed in past twenty years. The thirty years (1931 to 1960) normal values, highest and extreme highest values for India. Meteorological Department Observatory, Bamarauli, district Allahabad are given in Table 1. During winter the temperature is usually less than 13°C. Sometimes severe frost causes wide spread damage to the Rabi Crops. During the summer, hot wind blows constantly from the west with great violence imparting an intense dryness to the atmosphere.

1.5.4 PAN-EVAPORATION:

Pan evaporation values for the study area are not available. However some values are available for a neighbouring area, namely the Kanpur area. Table 2 gives pan evaporation data observed at the Chandra Shekhar Azad Agriculture and Technological University, Kanpur (C.A.A.T.U.K.).(See Ref.by communication and Prasad, 1973).

1.6 WATER TABLE:

Ground water occurs both in confined and unconfined state in the area (Bisaria and Roy 1976). In the southern part of the area, slope of the water seems to be steep and in the northern part, it is flatter. It is due to presence of the fine and coarse material respectively, in strata of these areas. Geological Survey of India has not, so far, determined the reduced levels of the study area; hence the

TABLE 1

NORMAL VALUES (1931-1960) OF TEMPERATURE AND HUMIDITY

Month	Humidity percent		Temperature in ^{o}C							
			Normal		Highest/Lowest		Extreme (Highest-Lowest)			
	Max.	Min.	Max.	Min.	Max.	Min.	Extreme highest	Date	Extreme lowest	Date
January	79	53	23.7	9.1	28.1	5.0	31.1	29.1.1934	2.2	20.1.1936
February	67	37	26.7	11.6	32.2	6.9	36.1	27.2.1896	1.1	2.2.1915
March	44	23	33.3	17.0	38.8	11.8	41.7	30.3.1931	7.2	2.3.1926
April	30	15	38.3	22.5	43.3	17.6	45.0	26.4.1931	12.8	3.4.1905
May	35	19	42.1	27.4	45.6	22.9	47.2	21.5.1922	17.2	11.5.1924
June	54	38	39.8	28.9	45.0	24.1	47.8	12.6.101	19.4	21.6.1930
July	80	71	33.6	26.6	38.6	23.9	45.6	1.7.1901	22.2	22.7.1955
August	85	78	32.1	26.0	35.6	23.8	40.0	1.8.1903	21.1	23.8.1953
September	81	71	32.8	25.2	35.7	22.8	39.4	29.9.1928	18.3	22.9.1922
October	69	52	32.6	20.4	35.4	15.5	40.6	3.10.1896	11.7	31.10.1898
November	66	45	29.0	13.1	32.4	9.2	35.6	4.11.1918	5.6	30.11.1941
December	76	51	24.8	9.3	28.3	5.8	31.1	2.12.1946	2.2	28.12.1902

Average of maximum and minimum normal values are $32.4^{o}C$ and $19.8^{o}C$ and extreme highest and extreme lowest temperatures were observed as $47.8^{o}C$ and $1.1^{o}C$ respectively.

TABLE 2

PAN-EVAPORATION DATA OBSERVED AT CHANDRASHEKHAR AZAD AGRICULTURAL AND TECHNOLOGICAL UNIVERSITY , KANPUR

Elevation 125.90 m, Location - Latitude 26°30' North and Longitude 80°15' East

Sl. No.	Name of Months	YEARS						
		1970-71 mm	1971-72 mm	1972-73 mm	1973-74 mm	1974-75 mm	1975-76 mm	1976-77 mm
1	April	273.0	183.00	245.10	64.20	309.00	300.00	255.90
2	May	313.1	241.80	455.08	342.55	324.88	379.44	319.92
3	June	244.8	204.00	441.00	204.90	300.90	275.10	291.60
4	July	192.2	171.12	142.60	150.97	128.34	129.99	145.70
5	August	105.4	84.94	145.70	140.74	106.95	128.96	101.99
6	September	129.0	111.90	159.00	114.00	141.00	105.00	120.90
7	October	145.7	104.78	89.90	120.90	125.24	109.74	141.98
8	November	94.5	96.00	93.00	94.20	102.90	96.90	94.80
9	December	86.8	68.20	76.30	70.37	74.71	73.47	74.09
10	January	77.5	75.95	73.74	80.60	67.89	60.45	78.12
11	February	92.4	96.28	94.92	108.08	92.68	104.40	104.72
12	March	167.4	176.08	178.87	213.90	189.41	180.93	203.36
	TOTAL	1921.8	1614.05	2195.21	1705.41	1963.90	1944.08	1933.08

exact slope of water table can not be computed (Bhatnagar 1965).

A water table map for May 1965, for the study area is shown in Fig. 7. From this map, it is clear that the water table in the study area is generally, at a depth of 4 to 6 meters below Ground level (G.L.) except in the area adjoining Ganga river where it is 16m to 18 m below the ground level (Bhatnagar 1965).

The Ground Water Investigation Organisation of U.P. , Lucknow, selected in 1972 a number of open masonry wells in district Allahabad, in, and, near the study area (Figs. 1 and 2) at which monthly observations of depth of water-table are recorded by its field staff. Table 3 gives a record of these water levels from 1972 to 1977 (Bahadur and Saksena 1976, and GWIO by communication)Only two observations in a year are shown in the table, one for the month of May (Pre-monsoon) and other one for the month of October(post-monsoon). Maps showing fluctuations in the water table are prepared for study area using these observations. One such map, for the year 1973, is shown in Fig. 8 (Bahadur et.al.1974), in which average rise from May to October, in the study area is indicated. In most of the areas ground water table is falling down. (Ref. IRI 1961, 1968 and 1969).

TEHSIL-HANDIA

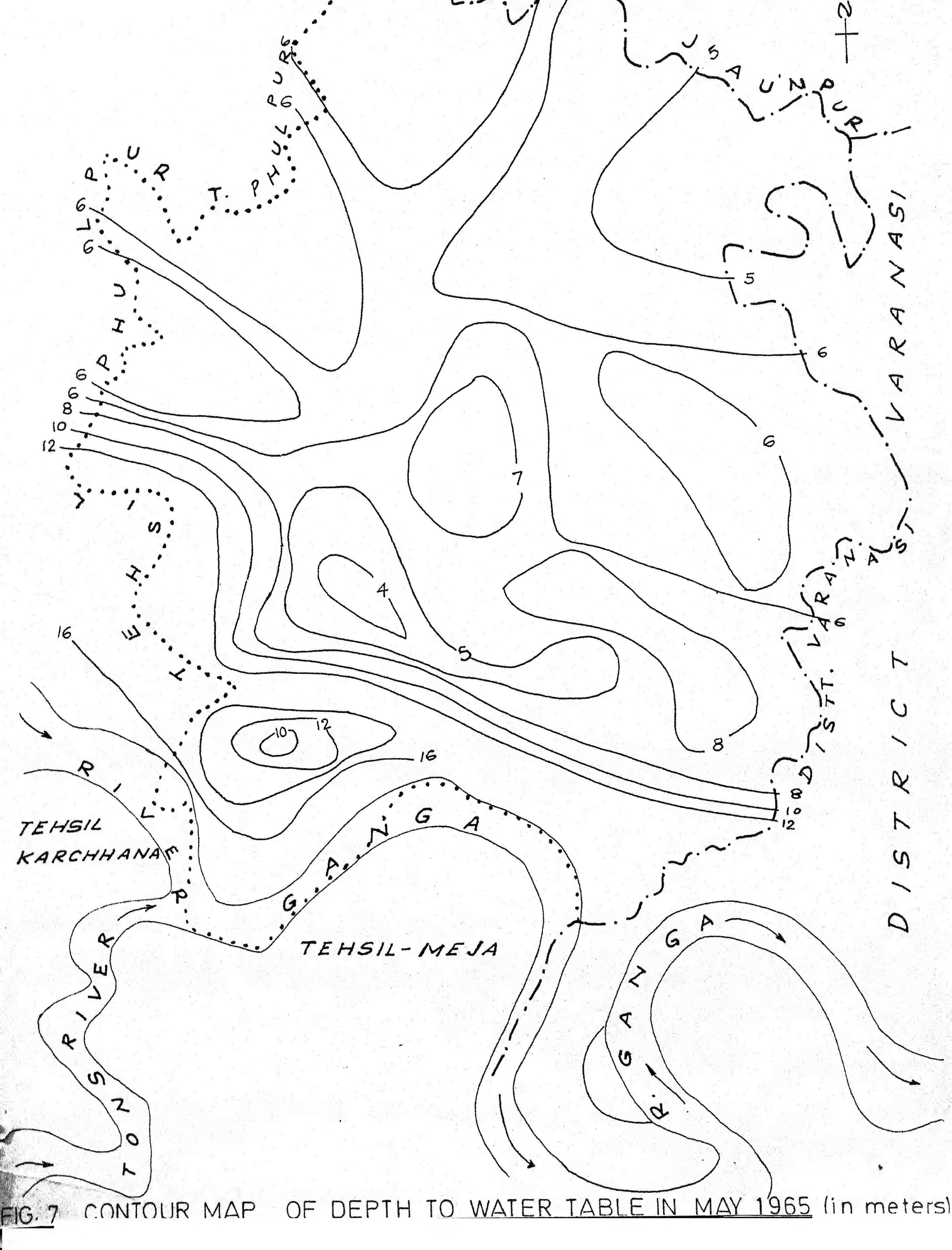


FIG. 7 CONTOUR MAP OF DEPTH TO WATER TABLE IN MAY 1965 (in meters)

TABLE 3

PRE-MONSOON AND POST MONSOON DEPTH TO WATER TABLE IN OBSERVATION WELLS (IN METERS)

Sl. No.	Well No.	Village	Tehsil	R.L.of Ground above mean sea level	Depth to Water Table Below Ground-Level											
					1972		1973		1974		1975		1976		1977	
					May	Oct.	May.	Oct.	May	Oct.	May	Oct.	May	Oct.	May	Oct.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	0/12A	Shila-khanna	Allaha-bad	-	18.13	16.25	13.00	13.00	18.15	16.00	18.75	15.60	18.60	17.63	18.97	Not available
2.	12	Rani-Mandi	-do-	-	10.15	9.15	10.38	7.10	9.80	8.95	11.80	9.10	11.50	11.46	11.93	
3.	13B	Mahewa	Karchana	-	15.10	13.30	15.82	8.70	14.15	11.48	14.50	11.20	15.45	13.17	15.87	
4.	13A	Dhanna	-do-	-	13.80	-	21.05	13.05	19.73	17.10	19.20	17.14	20.85	17.21	-	
5.	13	Ghur-pur	-do-	-	7.00	-	7.69	4.70	6.82	4.65	7.70	5.70	7.43	7.50	6.78	
6	14B	Umri	-do-	-	4.00	-	3.57	1.40	2.87	1.75	2.00	1.18	2.00	1.69	2.50	
7	14A	Kanti	-do-	-	3.00	-	3.39	1.10	2.89	1.75	2.20	1.28	1.98	2.46	4.00	
8	14	Misra Bandh	-do-	-	4.35	-	4.34	1.80	2.93	1.55	2.90	1.12	2.83	3.05	3.85	
9	15A	Jari	-do-	-	4.50	-	4.21	1.50	3.64	2.25	2.90	1.94	2.90	3.63	3.39	
10	15	Garha-iya	-do-	-	4.45	-	4.38	1.70	4.02	2.12	3.40	1.45	3.05	2.47	3.53	
11	15B	Dando	-do-	-	5.00	-	5.67	2.50	4.77	3.30	4.00	2.51	4.00	4.56	5.00	
12	9A	Harbha	Phulpur	-	4.15	-	4.82	2.90	4.45	2.27	5.10	4.30	5.97	4.80	6.70	
13	9	Sanwar	-do-	-	9.70	-	11.92	7.20	9.53	7.04	10.10	10.50	13.45	10.00	-	
14	10B	Munshi-Buzurg	-do-	-	4.30	-	5.42	3.60	3.88	1.95	5.80	2.00	6.50	1.75	5.50	

Contd.......

Table 3 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
15.	10A	Chila-udi	Phul-pur	-	10.15	-	12.67	12.00	11.79	9.10	12.50	14.40	Dry	14.05	Dry	
16.	10	Saha-nso	-do-	-	14.37	13.37	16.85	12.40	15.43	13.08	Dry	Dry	19.90	15.98	19.20	
17.	11D	Garapur	-do-	-	15.20	14.60	15.62	13.15	14.96	12.65	16.40	15.40	Dry	15.70	Dry	
18.	11C	Kusun-gur	-do-	-	12.60	12.50	13.87	10.50	13.38	11.00	15.30	13.05	15.95	13.20	15.55	
19.	New-Well	Hanuma-nganj	-do-	94.527	-	-	-	-	15.97	12.04	17.40	16.80	18.40	17.60	18.85	
20.	11B	Tharwai	Soraon	-	12.30	12.00	12.70	9.70	12.71	10.40	13.75	11.70	14.30	12.05	14.45	
21.	11A	Chakia	-do-	-	13.10	12.60	13.70	10.60	13.52	11.10	14.60	12.50	14.80	13.20	15.10	
22.	11	Old Pha-phamau	-do-	-	11.37	10.40	11.91	8.75	11.22	9.70	12.10	10.00	12.05	10.25	12.20	Not available
23.	OP-8A	Sirsa	Meja	93.729	16.05	13.77	18.15	15.55	17.25	14.23	16.20	13.65	16.90	14.46	13.35	
24.	8	Meja Road	-do-	31.242	7.09	3.12	5.79	4.64	5.44	3.46	5.25	3.30	4.42	5.13	5.50	
25.	8B	Tendua	-do-	91.132	6.49	1.39	4.49	4.69	3.36	1.59	4.30	2.58	4.07	4.03	4.85	
26.	8C	Meha (Town)	-do-	97.199	6.73	1.23	3.93	4.73	3.44	2.03	4.70	2.75	4.00	4.18	5.10	
27.	New-well	Nahavi	-do-	90.654	-	-	-	-	8.19	7.39	8.90	6.93	8.90	8.87	8.05	
28.	7	Handi-ya Bazar	Handiya	-	5.68	2.29	3.90	1.20	5.35	1.50	4.87	2.00	4.47	1.22	5.40	
29.	New well	Bhir-pur	Karchh-ana	89.984	-	-	-	-	10.78	5.53	8.25	7.03	10.35	9.13	11.65	
30.	-do-	Saida-bad	Handiya	90.996	-	-	-	-	3.61	2.56	4.66	3.50	5.05	4.60	5.21	

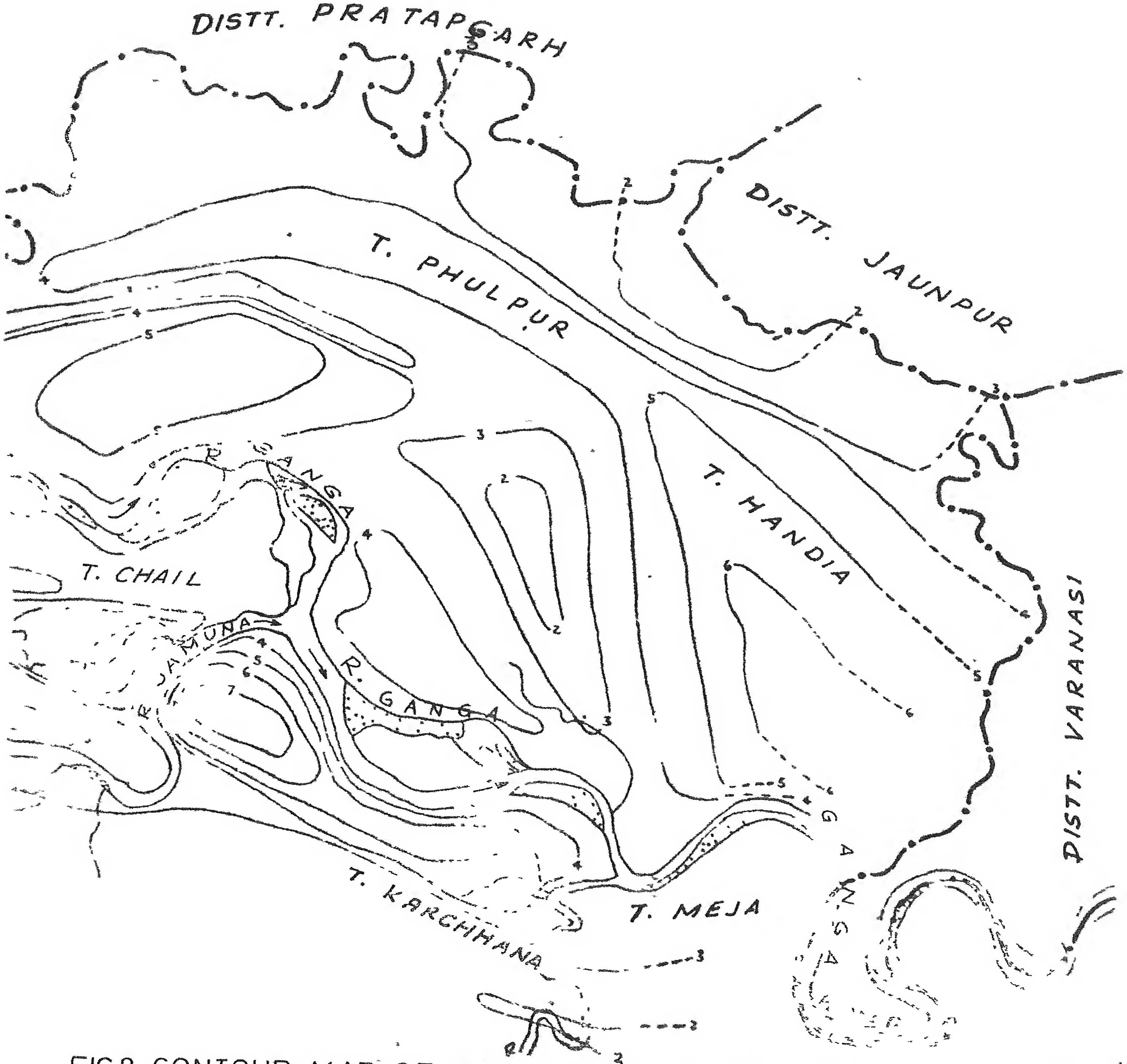


FIG.8 CONTOUR MAP OF WATER TABLE FLUCTUATIONS IN 1973 (in feet)

1.7 PEDOLOGY:

1.7.1 SOIL TYPES:

Soil is a mirror of the environment. Soil map shows the relative suitability for irrigation of the different soils. Both type of soils alluvial as well as residual soils, are available in district Allahabad. The Ganga - Jamuna alluviums have been developed by farmers by growing crops. The study area is covered by alluvial soils. The soils of the district have been classified as shown in Fig. 9 for the district of Allahabad (Mehrotra 1968; Bahadur and Saksena 1976).

1.8 LAND USE PATTERN:

Most of the land in the area is used for agriculture. There is no forest area. The area covered by tanks, 'Tals' (big ponds) etc. is also comparatively very small. Table 4 gives details of cultivated area on 1.4.1974 (Bahadur et.al. 1974, Bahadur and Saksena 1976).

The usual crops grown are Jowar, Bajara (Millet), Maize, Arhar, Paddy and Pulses in Kharif and Barley, Wheat, Gram, Sweet peas and Sugar Cane in Rabi. Certain traditional and new crop rotations adopted in the area are:

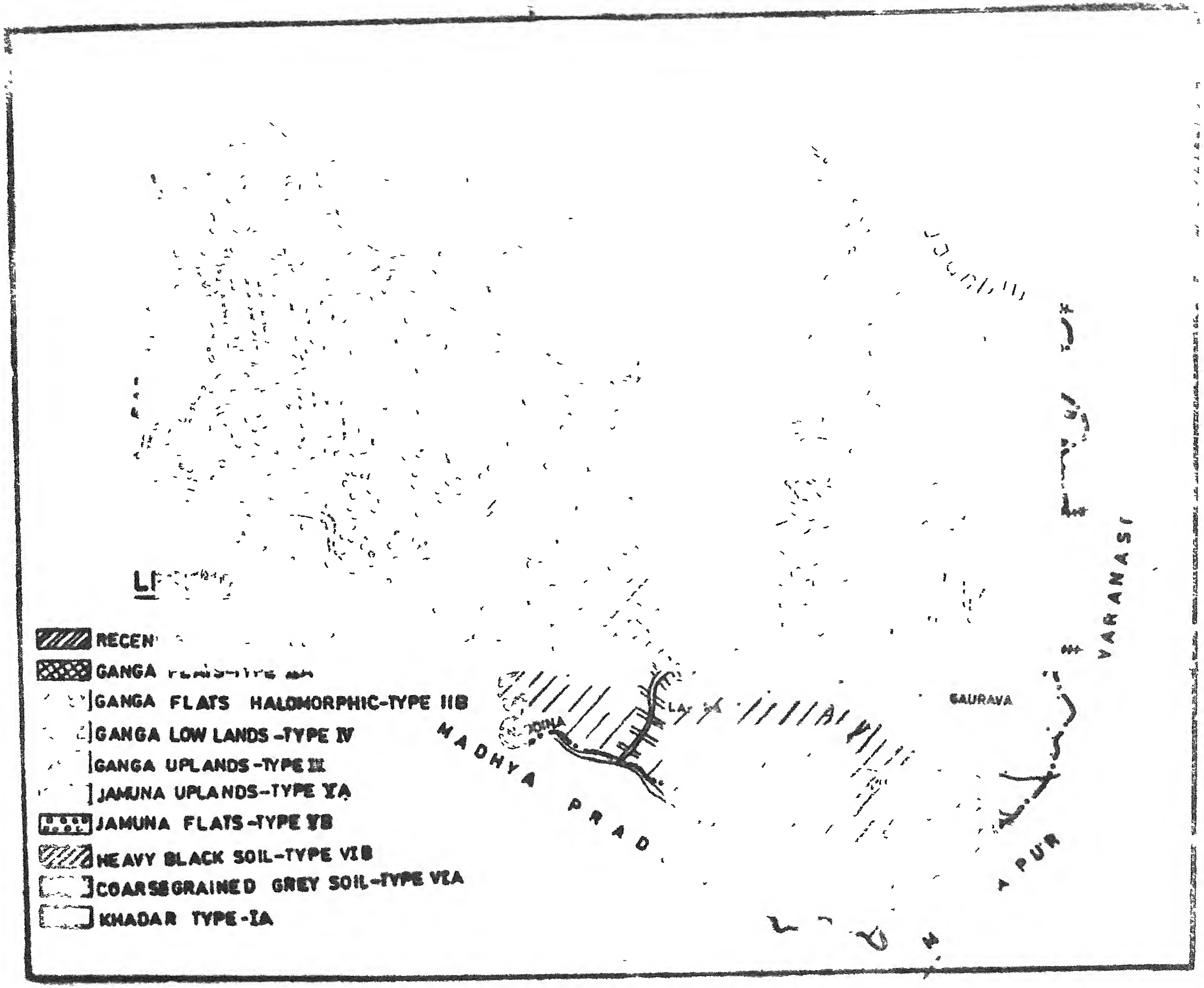


FIG.9 SOIL MAP OF DISTRICT ALLAHABAD
(Ref Bahadur and Saksena, 1976)

TABLE 4

BLOCK-WISE AREA AND IRRIGATION STATISTICS OF TEHSIL HANDIA, DISTRICT, ALLAHABAD ON APRIL 1, 1974

S.No.	Name of Block	M.I. Works		Total area		Cultivated area		Irrigated area		Unirrigated area	
		Name	Nos. on 1.4.74	Hectares	Acres	Hecta-res	Acres	Hecta-res	Acres	Hecta-res	Acres
1.	Handia	MW PTW PS	629 226 52	17408	43017	11104	34800	5140	12700	5964	22100
2.	Saidabad	MW PTW PS	1420 439 14	19688	48650	14160	35400	6234	15585	7726	19815
3.	Pratap-pur	MW PTW PS	1876 308 48	18211	45000	13311	33275	7214	17320	6097	15455
4.	Dhanu-pur	MW PTW PS	978 409 222	22553	55730	15863	42300	6510	16100	9353	26200
	TOTAL	MW PTW PS	4903 1382 336	77860	192397	54438	145775	25098	62205	29340	83570

Traditional crop rotation

(1) Bajara-Arhar-Fallow-Barley or Wheat (Mehrotra 1968)

(2) Paddy-Fallow-Maize-Wheat or Barley or Gram.

(3) Early Paddy Wheat or Barley or Peas.

New crop rotation

(1) Taichung-Native Peddy-Wheat Maxican.

(2) Hybrid Maize-Wheat-Maxican.

Some of the crop rotation adopted by the farmers of the localised area are:

(a) Fallow-Wheat-Chari-Gram or Peas

(b) Maize-Patato-Urd and Moong-Wheat or Barley-Sanai Fibre.

(c) Maize-Patato-Gram-Arhar-and Jowar.

(d) Fallow-Wheat-Maize-Peas Sugar Cane.

At certain places Pippermint Plant crops are grown in summer which require frequent irrigation during the season. (Ref. I.C.A.R. 1968).

1.9 PROGRESS OF IRRIGATION:

In this area there is no canal irrigation to date, but only well irrigation. In well irrigation, generally shallow wells (masonry wells) were prevalent in the area and some irrigation was done from ponds. Development of ground water, in this area, was undertaken by the State Government, Irrigation Department about 23 years ago (1955).

Due to the success of a number of state tube wells (STW) constructed by German Water Development Agency, there has been a rapid growth in deep tube-wells since 1955 in the area. With the result there were 288 number energised deep STWS in 1976-77 in the area, These state tube-wells vary in depth from 61 m to 155.5 m (200 ft to 510 ft). After the German Water Development Agency, the State tube-wells were constructed by Exploratory tube-well Organisation (ETO) , Government of India, Rigs Division Varanasi and Rigs division Allahabad of State U.P. Irrigation Department, under various projects, such as 110, 500, 239, (739), 800, 1320, 2500 Tube-wells projects etc. Fig. 10 shows yearly growth of state tube-wells (STW) and draft from the year 1955-56 to 1976-77.

In addition to these STWS' there has been a growth in the Minor Irrigation-Works (MIWS) also such as private tube-wells (PTW), pumping set (PS) and Masonry Wells (MW). Until 1976-77, there were 5129 MWS; 397 PSS' and 2387 PTWS'. Fig. 11 shows the yearly growth in the number of these Minor Irrigation works and their draft over the years. (Reference personal communication, MIDn Bahadur and Saksena 1976 , Table 4, Kumar et.al. 1974 and Bahadur et.al.1974).

Progressive increase in the cumulative draft from

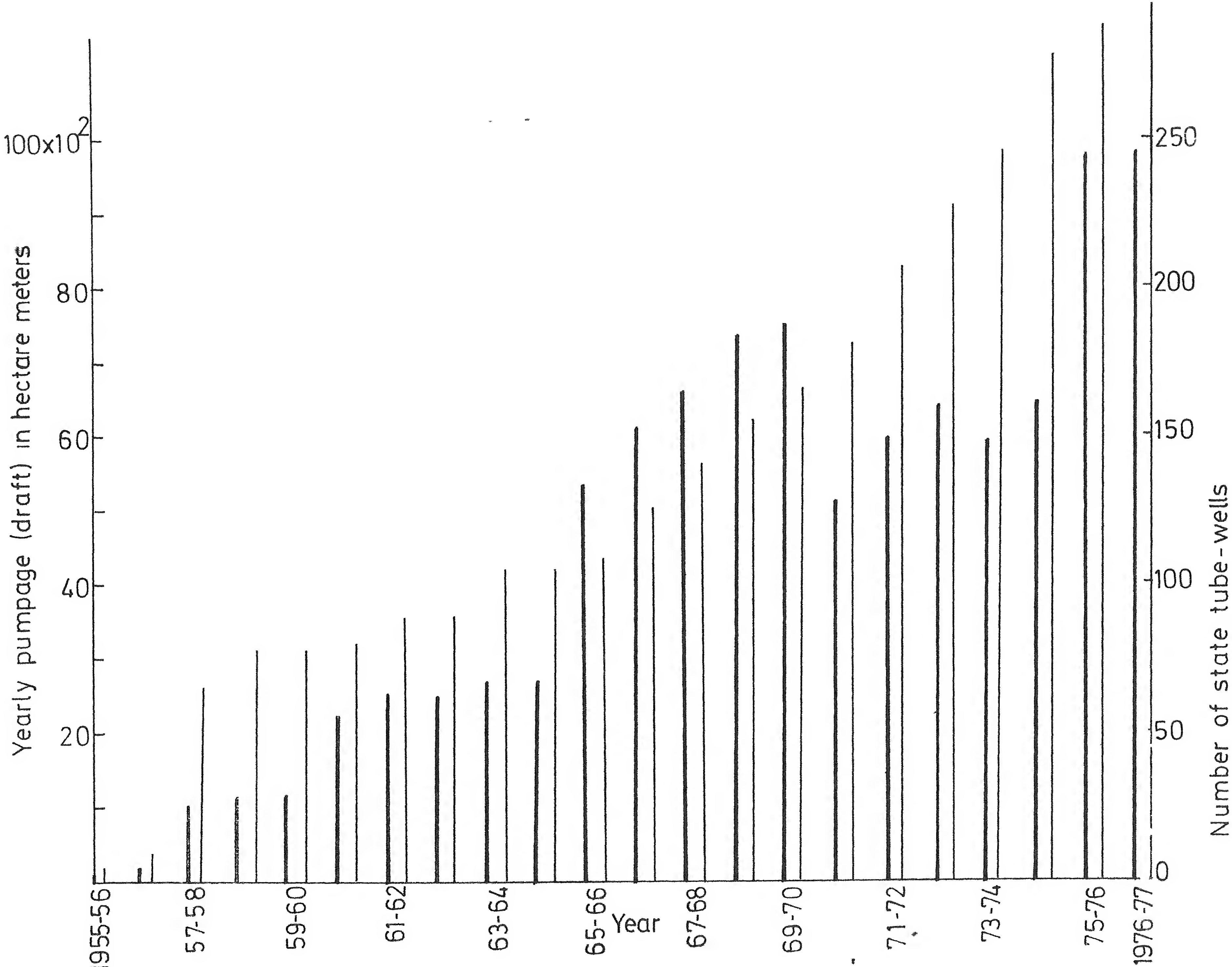


FIG.10 PROGRESS OF STATE TUBE-WELL DEVELOPMENT

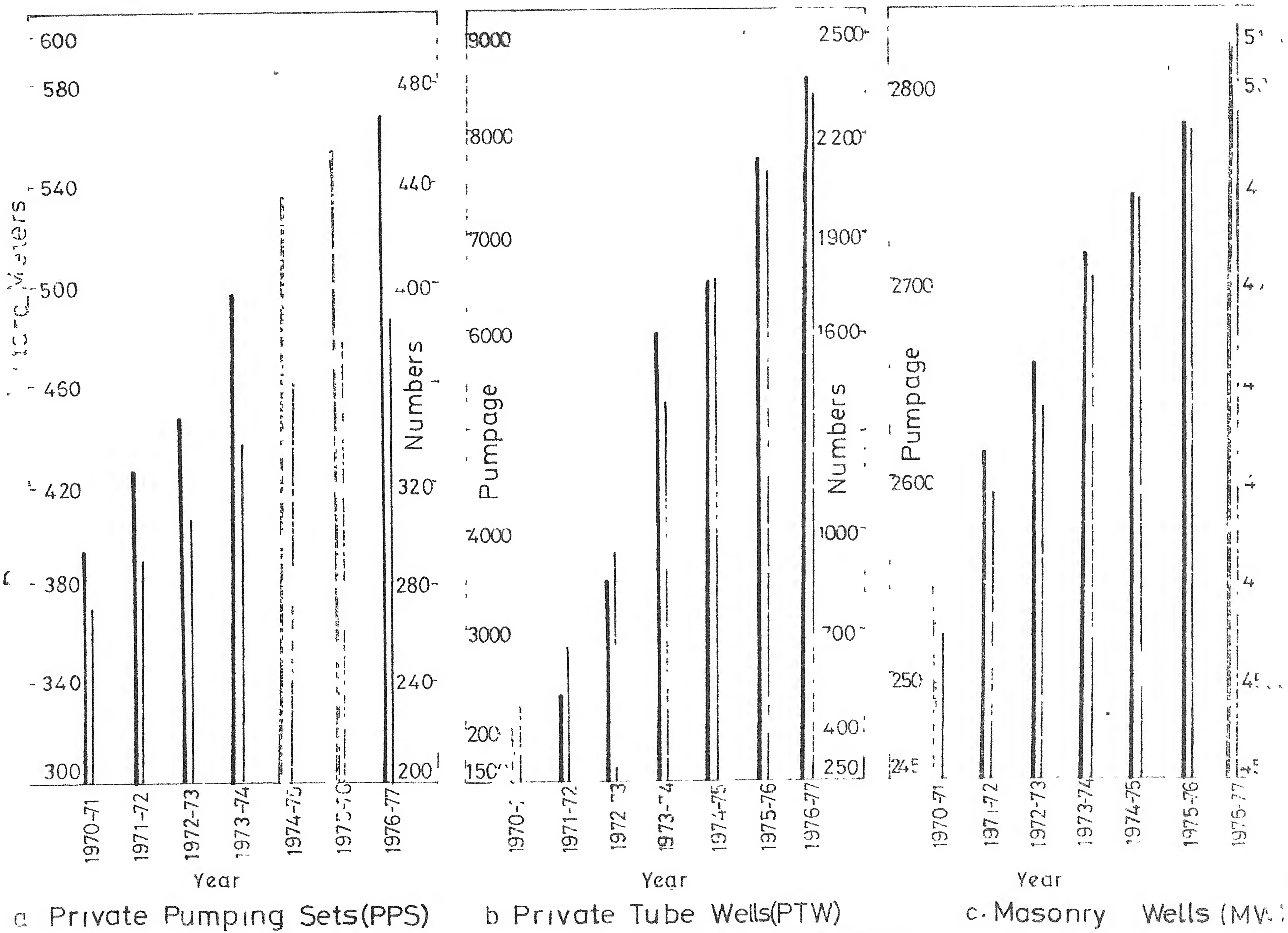


FIG.11 PROGRESS OF MINOR IRRIGATION WORKS

the study area are also shown for STWS' and MIWS' in Fig. 12 and 13 respectively. It may be seen that the total cumulative draft in the year 1976-77 from the MIWS' (i.e. .W, PS and PTW) was 12233 hectare meters (99,455 acre feet) compared to 4693.3 hectare meters (38,157 acre feet) in the year 1970-71. Similarly, the total draft from STWS' for 1976-77 was 9801.8 hectare meters (79,683 acres feet), compared to 48.5 hectare meters (3944 acre feet) for the year 1955-56 (see Fig. 12).

Total draft from state tube-wells was computed by an averaging process. The whole of 22 years period from 1956 to 1977 was devided into six intervals three of 5 years duration each (i.e. 1956- 1970), one of three years duration (i.e. 1971 to 1973) and two of 2 years duration each (i.e. 1974 to 1977). A certain number of state tube-wells were selected out of total number of energised STWS' in each of the years and their average discharge and running hours were computed for each interval of time mentioned above and for each Kharif and Rabi crop separately. From these average discharges and running hours of the selected STWS' of a particular year and crop, per STW mean average discharge and running hours for each time interval was calculated. To calculate the yearly draft from the state tube-wells some model calculationsare given in Annexture 1.

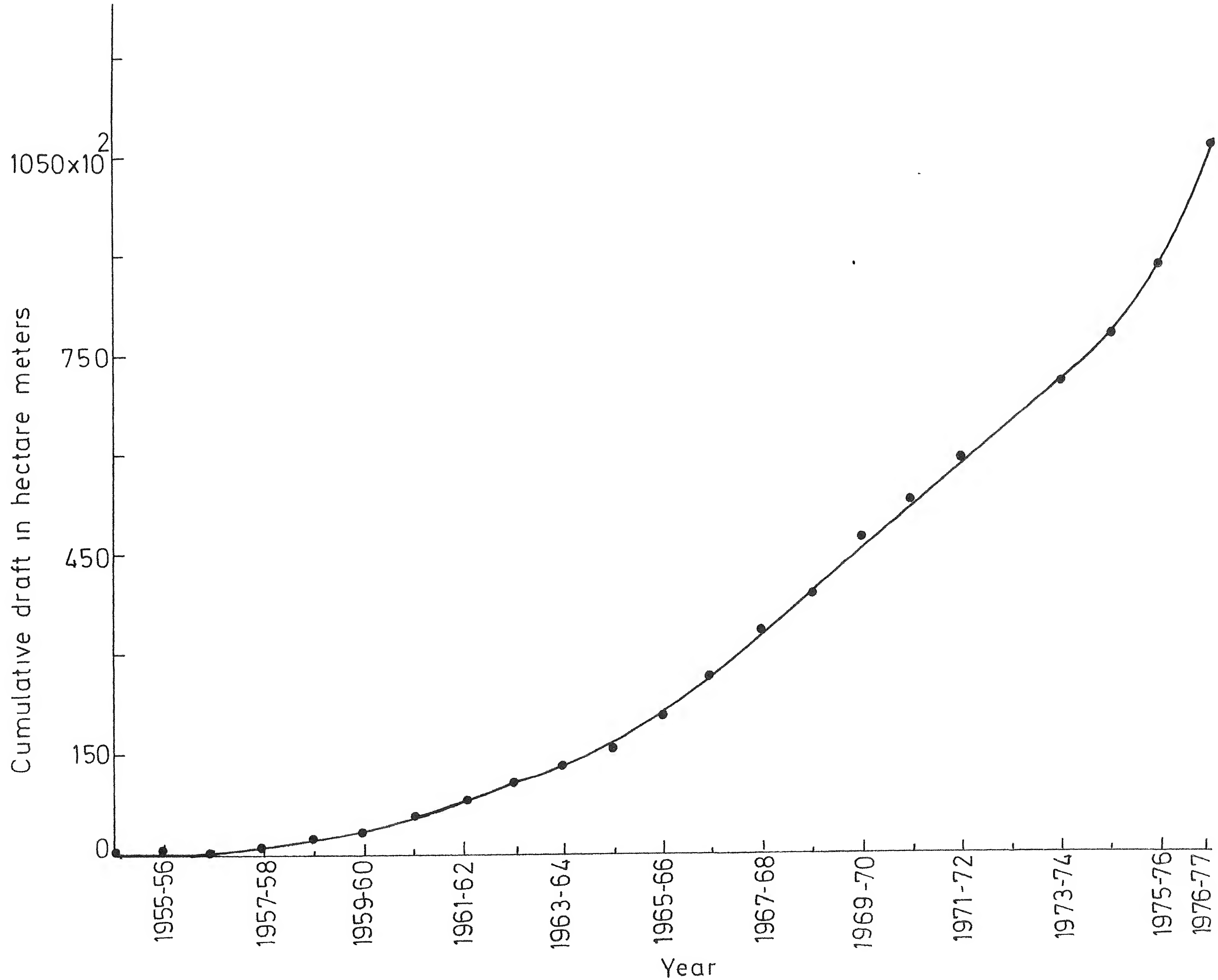


FIG 12 PROGRESSIVE CUMULATIVE DRAFT FROM STATE TUBE-WELLS

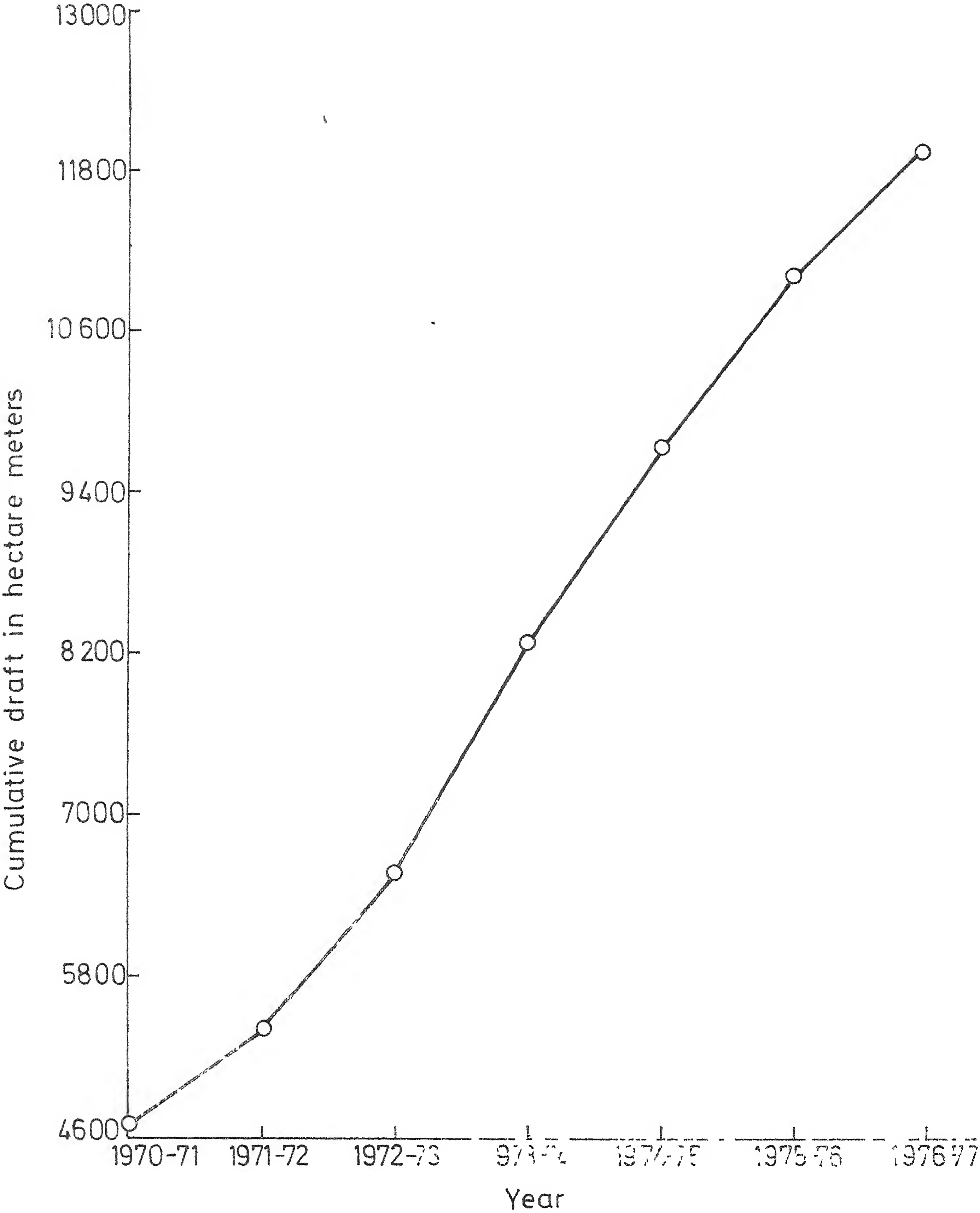


FIG-13 PROGRESSIVE CUMULATIVE DRAFT FROM MINOR IRRIGATION-WORKS

It is observed that the water table has been going down over a large part of the study area. If this process continues many of the shallow wells will be out of use. Further, it is observed that even the deeper state tube-wells are affected because of the water level going below the pump bowl assembly. It is therefore necessary that the operation of the ground water basin should be such as to control this problem by a suitable plan of pumping and recharging. It is the endeavour in the current investigation to formulate a simple mathematical model for the basin and study the effects of large scale pumping. Effects of artificial recharge to control ground water levels is also studied.

CHAPTER II

2.1 LITERATURE SURVEY:

2.1.1 HYDROGEOLOGICAL STUDIES IN GANGA BASIN:

Hydrogeological studies in India were started in 1804. State tube-well (STW) scheme in U.P., called as "Ganga Valley tube-well Irrigation Scheme" began under Sir Willium Stampe in 1934. Taylor (1936) worked on this scheme and prepared a report on the possible lowering of water table due to tube-well pumping. According to him sub-surface water pumping would not affect the existing stability of water table. In years of low rain fall there would be fall in the water table which would be recovered in years of normal and heavy rainfall. In 1948, Johonston International (U.S.A.) was engaged to study and report the feasibility of large-scale tube-well irrigation development (Jones & Hofmann 1967). Irrigation well construction projects were started in 1951 and certain efforts for systematic studies at some places in the country started in 1953 with the inception of All India Ground Water Exploration Project.

After 1938, in almost every tract of Uttar-Pradesh, where state tube-well irrigation was introduced, the water-table appeared to move downward continuously. As this

continuous lowering of water-table and growing demand of state tube-wells were a matter of great public concern, hence Bhattacharya (1954), carried out some studies and analysed data for 18 years period (1934-1952), for seven doabs east and five doabs west of Ganga. He concluded that the water-table had stablized at a lower level and there was no progressive lowering.

Pathak (1954) in his preliminary report on ground water conditions described criteria for sites for exploratory bore holes in U.P. The same author in 1955, carried out his studies on ground-water occurrence in the alluvial tracts of U.P., and described shallow and deep aquifers in which former one is under water table conditions and the later one under confined conditions.

Nautiyal (1955) studied artesian water supply of Tarai and Bhabar zone of U.P.

Taylor (1959) on the basis of hydrogeological characteristics, methodically arranged the Indian subcontinent into eight ground water provinces, and divided the whole gangetic basin into Bhabar, Tarai and gangetic plain regions.

Pandey, Raghav Rao and Karnath (1961) evaluated the ground water potentialities of Bhabar zone of U.P.

Mehta and Adyalkar (1962) carried out similar studies

on Tarai and Bhabar zones including sloping plains along Himalayan foothills. Bhabar zone was described as recharge region and where the aquifers were unconfined and under water table conditions, which tended to be confined on the southern margin of the zone, only when there was a variation in the slope.

Chaturvedi and Pathak (1963) analysed certain pumping tests data of the Indo-Gangetic plain and described variation in hydrogeological characteristics of the aquifers of this area. The same authors also studied flow of ground water towards wells in the vicinity of a perennial stream i.e. upper Ganga Canal and gave their findings regarding recharge boundary effect. In 1965, they further studied the flow of ground water towards pumping wells and the optimal yield under varying geohydrological conditions and recommended safe design discharge for STW as 0.063 cumec (2.25 cusec) instead of .042 cumec (1.5 cusec). Average coefficient of transmissibility for the area studied by them was worked out as .045 cumec/m (0.479 cusec/ft) and storage coefficient as 20%.

Regarding area of Aligarh and Bulandshahar districts they reported as follows :

"Replenishment of the water-table in this area would no doubt take place from year to year under the influence of local rainfall penetrating the water-table. As the confined

water underneath the clay layer, it is also likely to be replenished by the leakage from above to a certain extent, so long as the water-table is above the piezometric surface of the confined aquifer".

Singhal (1963) studied some aspects in application of pumping test-methods to specific field conditions.

Raghav Rao (1965) evaluated formation constants of Saharanpur district area and classified aquifer of the area as confined.

Singhal and Gupta (1966) concluded that deep aquifers in Meerut and Mujaffar Nagar areas indicated leaky confined character locally. They also observed value of 'T' and 'S' varying with pumping time.

Jones and Hofmann (1967) presented a comprehensive report under water resources investigation programme for upper Gangetic plain. These authors dealt with the topography climate, teclonic frame-work, geology, hydrology, hydrogeology, geophysical and various other aspects of surface and ground water activities. They evaluated all the then existing records and analysed critically the various studies, methods and results pertaining to other investigations. They described that interconnected sand-bed aquifers form the ground water reservoir, which is hydraulically continuous throughout most of the plain. This continuity is either because of inter-

lamination of braided stream and meander belt deposits.

Gupta (1968) carried out hydrogeological studies in Muzaffar Nagar and parts of Meerut district and applying Jacob method he made efforts to establish certain relationship between precipitation and rainfall penetration to the shallow ground water table.

Mithal (1969) gave a reapraisal of ground water distribution and provinces in India. He sub-divided Indo-gangetic alluvial province into seven provinces, considering several parameters like structure, well and recharge characteristics.

Pathak (1969) outlined regions of artesian flow in Basti, Gorakhpur and Deoria districts of U.P.

Dubey (1969) studied the depths and fluctuations of ground water table as a result of discharge and draw-down due to local pumping. He also stated the peculiar characteristics of Bhabar and Tarai zones.

Chaterjee (1969) described Ganga basin alluvial tract can yield more than 100 m^3/hour at a draw down of less than 10 meters. He also indicated the potentialities of Vindhyan sand stone to be tapped as aquifers within the weathered zone.

Mithal, Singhal and Bajpai (1973), they also have been given outline of the ground-water conditions and revealed the

deep aquifers as leaky confined nature. According to these authors the aquifers followed lithological continuity in North-South sections while in the East-West direction it was discontinuous.

Venkatachaliah (1974) worked out coefficient of transmissibility for I.I.T. Kanpur campus area, which varied from 23×10^5 to 44×10^4 lpd/m. for deep aquifers while for shallow aquifers it varied from 30×10^4 to 38×10^4 lpd/m. He also reported specific capacity varying from 241 to 416 lpm/m for deep and 168 to 196 lpm/m. for shallow aquifers.

Saksena (1974) computed values of transmissibility T, coefficient of storage S and leakance $\frac{K'}{b'}$ by various methods. According to him values of T, S and $\frac{K'}{b'}$ varied from $.097 m^2/min$ to $2.94 m^2/min$, 2.48×10^{-3} to 118.0×10^{-3} and 1.1×10^{-5} to 10.0×10^{-5} respectively. He reported specific yield as 0.118 and recharge due to rainfall as 255 mm. for the Ganga Ramganga doab.

He further concluded as below :

"The present maximum, safe-yield has been worked out as 4,01, 300 hect m. and the utilizable safe yield as 2,80,900 hect m. The present draft on account of all sources is 2,53,800 hect m. the balance availability thus being only 27100 Hect m. An extra recharge of 21,000 hect m. shall be available due to recent construction of Ramganga feeder. However this may not be sufficient to meet future demand of ground water for

irrigation and hence artificial recharge will also be essential in the doab."

Bahadur and Saksena(1975) gave an appraisal of ground water potential in U.P. and made some efforts for evaluating the utilisable annual ground water potential or safe yield as 52.55 lakh hect.m. (42.5 million acreft) while actual drawl of ground water was calculated as 27.00 lakh hect. m. for the year 1973-74. On the basis of economic running hours of tube-wells state of U.P. is committed to utilize 41.20 lakh hect.m. as annual drawl of ground water.

Bahadur and Saksena (1976) presented a preliminary report on geohydrological investigation to design well field near Phulpur project area and evaluated formation constants for the area.

Pathak, Venkatesan and Bhattacharya (1976) reported the results of exploratory drilling carried out over the last two decades. Highly potential aquifers which can yield 180 to 360 m^3/hr for economic drawdown have been located with a depth ranging from 250 m to within 600 m in the Central Ganga Alluvial Plains. It has also been observed that the clay beds lying over the confined aquifers progressively increase in thickness from Kanpur eastwards.

In certain very potential aquifers, though commonly lanticular thin and limited in extent, have been found to

exist in the south of the Marginal Alluvial Plains shallow tube-wells, with a depth ranging from 45 to 100 m and water level ranging 7.0 to 26.0 m below ground level, generally yielding 60 to 240 m^3/hr for economic drawdowns of the order of 3 to 16 meters, have been constructed.

Bisaria and Roy (1976) carried out their studies regarding ground water resource of Mainpuri District and reported that there are two prominent aquifers within 150 m. below ground surface. Average total thickness of the aquifers at depths of 30 m and 100 m was reported as 12m and 44 m respectively.

Chaturvedi (1977) carried out hydrogeological investigations in the neighbouring district of Mirzapur and reported values of transmissibility coefficient ranging between 15000 to 25000 gpd./ft. with field permeability around 300 gpd/ft. and specific capacity ranging between 770 gph/ft and 1560 gph/ft.

2.1.2 INVESTIGATIONS IN THE STUDY AREA:

So far no detailed hydrogeological investigations of the study area have been carried out. Whatever studies have been made todate, are related mostly to the behaviour of the water table in the upper strata.

I.R.I. (1968, 1969) carried out some studies pertaining to the behaviour of ground water tables in Ganga-Ghaghara and

Ganga-Sarda doabs and concluded the then drawl through tube-wells as within safe limit.

Recently, some efforts have been made by newly created Ground Water Investigation-Organisation, Lucknow, to carry out some preliminary studies for certain isolated areas, which are compiled (unpublished) as technical feasibility reports for Minor Irrigation Projects. These projects relate mainly to dugwells and private shallow tube-wells.

This organization carried out some preliminary studies in the area, and calculated annual recharge of ground water on the basis of water table fluctuations of 2.5 to 2.9 m due to rainfall and a specific yield of 9%.

Work of certain other authors pertaining to the study area is mentioned below.

Bhatnagar (1965), during his field season 1964-65, carried out some geohydrological studies in part of Allahabad and Mirzapur districts, and recorded depth of water tables, temperature total depth and diameter of dug wells. He also collected water samples and evaluated coefficient of transmissibility by conducting a pumping test at Rudapur, state tube-well of Phulpur Tehsil as 536.8 m^2/day. Total depth and pumping rate recorded for this tube well are 63.99 m and 403 gpm respectively.

Khanna (1973 and 1974) reviewed the work of Bhatnagar and studied ground water conditions in district Allahabad and summarized the draw down, discharge and specific capacity values for alluvial aquifers of northern part of district Mirzapur.

Kumar; Singh, Malviya and Bisaria (1974) studied technical feasibility of ground water development on compact area basis in Phulpur, Baheria and Bahadurpur blocks of Tehsil Phulpur and Pratappur block of Tehsil Handia. Chemical quality of ground water was also examined. They assumed unit draft for private tube-wells as 3.7 hect.m. (30 acre ft) and for STWs' 54.12 hect.m (4

Bahadur, Asthana, Bisaria, Malviya and Sharma (1974) did the same for district Allahabad assuming unit draft as 2.22 hect m. (18 acre ft.) regarding private tube-wells.

All these authors assumed the unit draft for Rahets, Masonary Wells (MW), Pumping Sets (PS) and State Tube Wells (STW) as 0.55 hect.m. (4.5 acre ft), 1.48 hect.m. (12 acre ft.) and 34.53 hect.m. (280 acre ft.) respectively.

Bahadur & Saksena (1976) studied status of ground water in Ramganga command area from the viewpoint of geology, hydrogeology, meteorology, climatology and various other parameters. They evaluated water balance in the command area assuming the above mentioned unit drafts except the one for

state tube-wells which was taken as 40 hect. m.

2.1.3 MATHEMATICAL MODELLING AND SIMULATION TECHNIQUE:

There is voluminous literature on mathematical modelling, analog and digital computers applied to ground water problems.

Walton and Neill (1960) used technique of mathematical models and a digital computer to analyse ground water problems.

Walton (1962) gave a sample programme and flow chart and suggested analytical methods for evaluating characteristics of well and aquifer of Chicago area.

Ferris, Knowles, Brown and Stallman (1962) described a procedure for setting up the image wells which can replace the geometric boundaries and gave theory of aquifer tests.

Walton and Prickett (1963) gave a very clear account of the analog. simulation of the aquifer system in Illinois U.S.A.

Tyson and Weber (1964) reported the use of a general purpose analog and digital computers for the coastal plain of Los Angles (U.S.A.).

Hantush (1964) gave formulae for draw down and evaluating formation constants, if the complex aquifer system is replaced by a leaky artesian or a water table aquifer.

Remson, Appel and Webster (1965) gave a solution to

the problems of ground water system, by Digital computer and described that an asymmetrical finite difference networks is easier to solve problem arising due to cumbersome and very irregular geometry of the boundary.

White and Hand (1965) made an electric analog analysis of San Simon Basin, Arizona (U.S.A.) and constructed a two layers model. They also made a similar analysis for Cochise and Graham counties in Arizona.

Moore and Leonard (1967) reported the data requirements and preliminary results of an analogue model evaluation of the Arkansas River Valley in Eastern Colorado (U.S.A.).

Prickett and Lonnquist (1968) gave a comparative study of analog and digital simulation technique applied to various situation.

Radhakrishnan (1969) deals with a new technique of direct simulation analog computer and its limitations. The new technique of continuous resistance electrical analog in place of discrete or fixed resistors in the net work along with its advantages principles of design are also given in his report.

Rushton and Bannister (1970) reported on slow time resistance capacitance analog as an alternative to the usual fast time analog.

Lakshminarayana (1971) reviewed electric analog models for management of aquifers with the help of some examples of mathematical models for simple and complex geometrical boundaries. According to him the model can be useful if the historical data are reliable. Reliable analytical, analog and digital models can then be developed for efficient management of the aquifers.

Lakshminarayana, Subramanium, and Kognolkar (1975) developed a direct electric analog model based upon the analogy between the flow of electric current and laminar flow of fluid. They used it for studying the response of an aquifer for various pumping and recharging schemes.

Ramaseshan (1976) described steps for digital simulation and choice of computers by explaining their utility, performance and accuracy.

The same author gave a note under the heading of analog simulation and described briefly various procedures such as scaling, checking and others applications of the analog computer.

CHAPTER III

3.1 HYDROGEOLOGY:

The hydrogeology of the area under study, is complicated. The bore hole sections north-west to south-east (line Y-Y') and south-west to north-east (line X-X') (see Fig.2) passing through the central and southern part of the area respectively, show the presence of three hard clay (or its admixture with kankar) horizons, separated by two sand horizons comprising mainly of fine to medium sands. It can be stated that besides the shallow aquifer and occassional perched aquifers within the thick back swamp clay (or clay mixed with kankar) horizons (thickness varying from 15 m to 50 m) there are two prominent and persistent fine to medium aquifers within 155.5 m below ground level. The average of the total maximum thicknesses of these upper and lower granular zones, upto the depth of 76m and 155.5 m, are 15 m and 76.2 m respectively. These two principal aquifers are further split up by the clay wedges. Hence due to the presence of a number of lenticular sand layers in the intervening clay-silt horizons. The total thickness and the apparent numbers of the granular horizons vary from place to place as evident from Fig. 3, 14, 15, and 16.

Sub-surface geological cross sections (correlation) of the aquifers has been attempted and tentatively worked out

on the basis of the lithological-logs of different bore-holes drilled in the area along line X-X', Y-Y' and Z-Z' (See Figs. 14, 15 and 16).

Despite best efforts all the information regarding details of slots or mesh-opening of the strainer, sizes of gravels and sieve-analysis of aquifer materials, the water quality, and all the total strata charts for 288 nos.bored state tube-wells could not be obtained for the study areas. The available strata-charts were used for visual classification of different aquifer materials. Figs. 3, 14 , 15 and 16 shows typical strata-charts of the aquifers in the region. It may be seen from the figures , that as we go below the ground level, we come across horizons of silty loam, hard clay mixed with kankar, sandstone and fine sand of thicknesses generally, in the range of 3 to 8 m, 15 to 50 m, 0.3 to 3 m and 7.5 to 53 m respectively. The sand (fine, medium, and coarse) gravel and the kankar-rich silt clay layers are the main store house of ground water in the study area. There are occassional layers of coarse-sand, gravel and kankar, within the sand horizons. The sands are generally reddish and greyish in colour and the coarse sand is commonly comprised of angular to sub-rounded grains of quartz. All the available data are shown in Annexture 2. History charts of working of STWS' and pump efficiency registers were also studied as shown in Annexure 1, (Ref. by communication UPID).

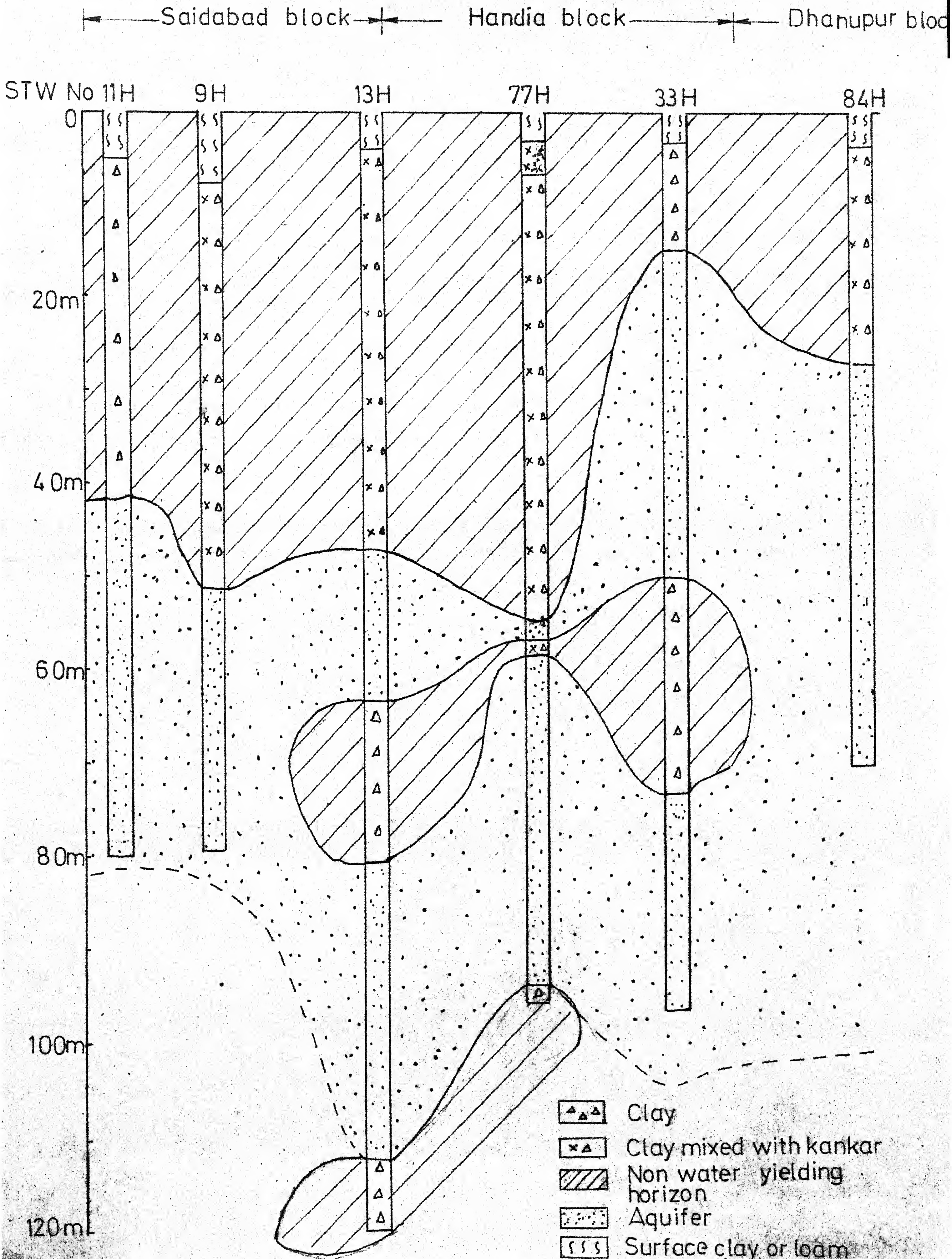


FIG.14 GEOLOGICAL CROSS-SECTION ALONG LINE YY' (X-X')

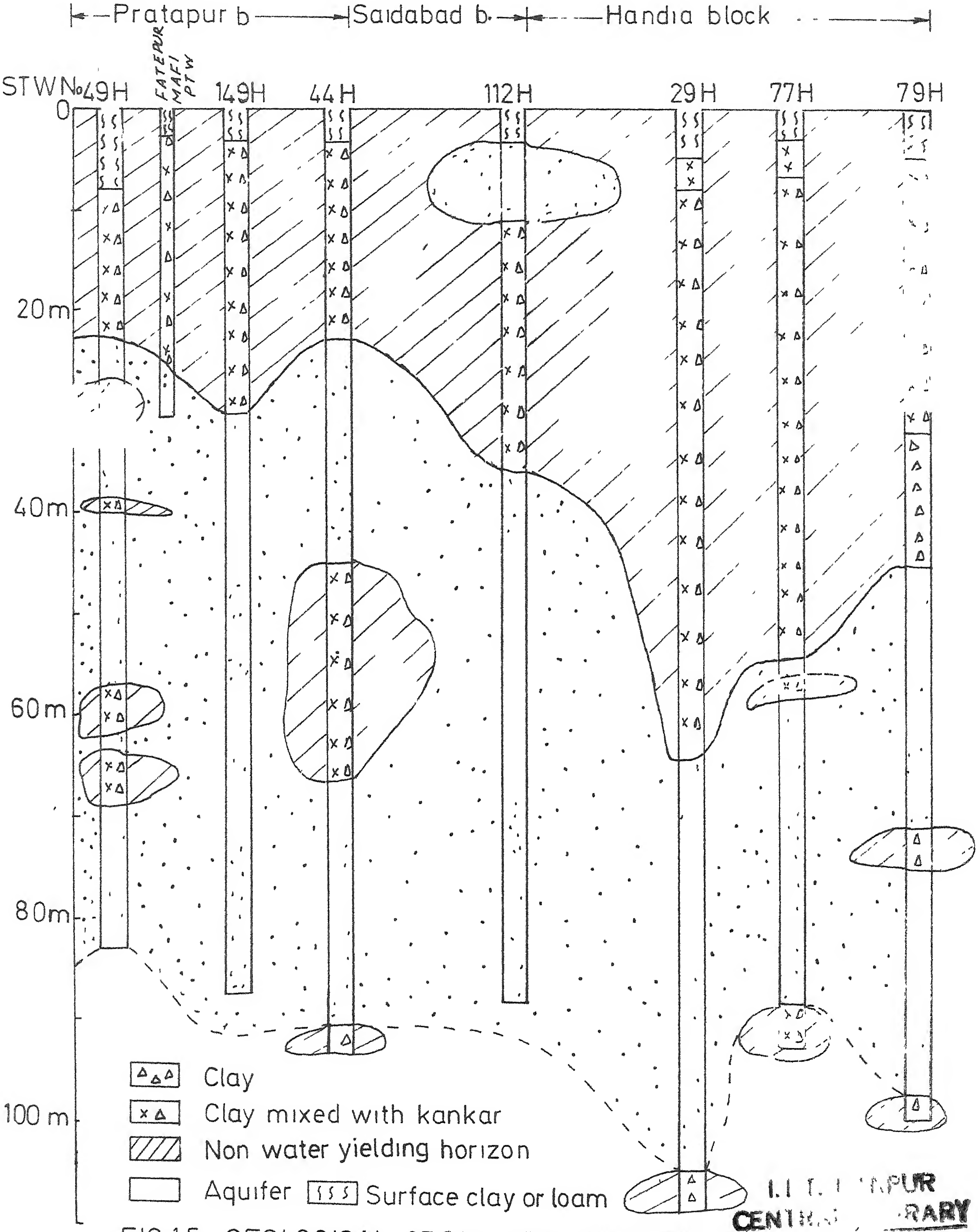


FIG.15 GEOLOGICAL CROSS-SECTION ALONG

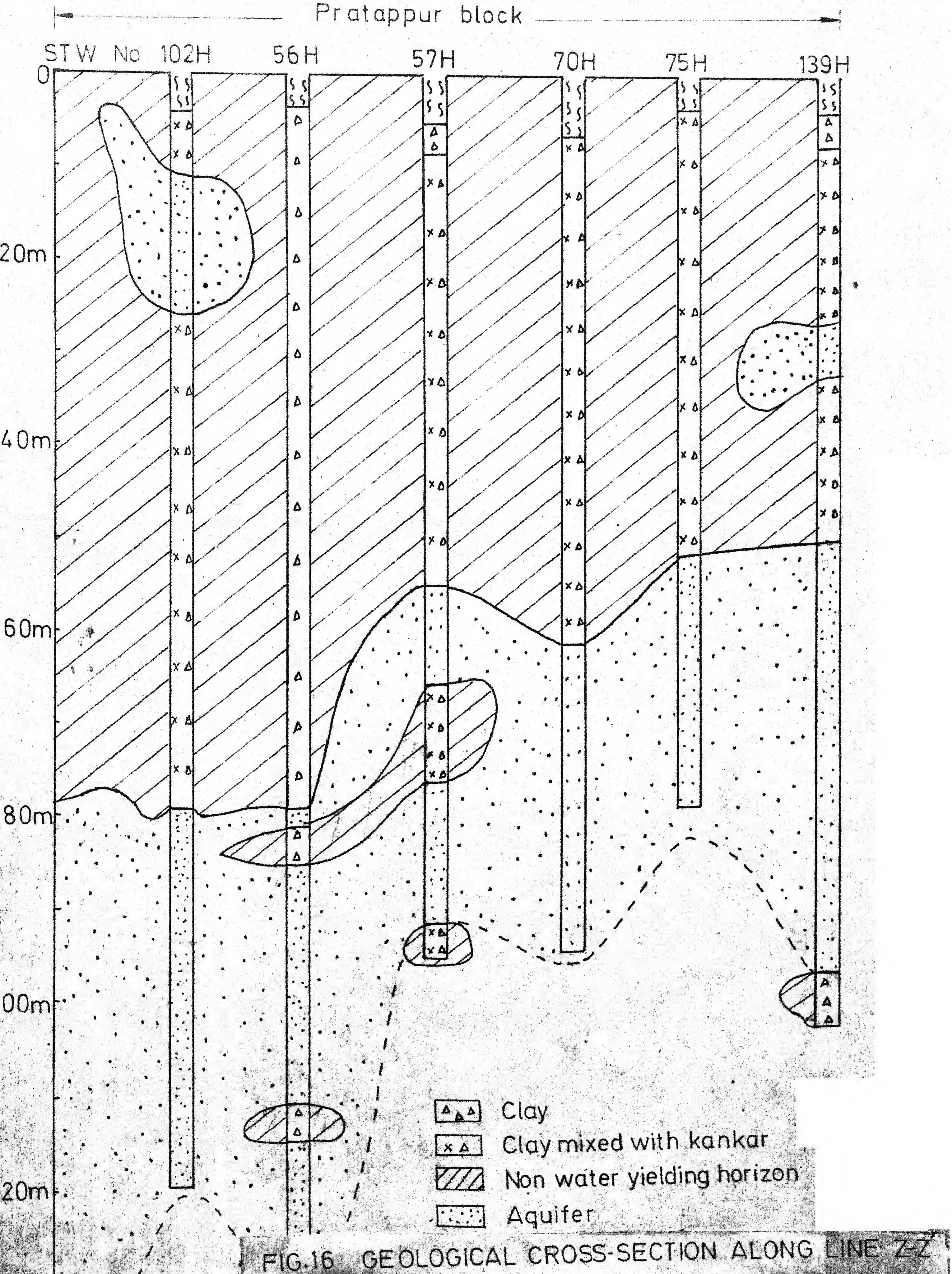


FIG.16 GEOLOGICAL CROSS-SECTION ALONG LINE Z-Z'

3.2 PIPE ASSEMBLY DETAILS:

A number of state tube-wells (288 nos) were drilled to explore the ground water potential and they are being used to augment irrigation supplies in the area of study. The typical assembly details along with strata-charts are shown in Figs. 3a, 3b and 3 c. As per personal knowledge of the author, three types of pipe assemblies have generally, been installed in the study area:

(1) M.S. pipe assembly having 300 mm Ø casing or housing pipe, 150 mm Ø blind and 150 mm Ø slotted pipes connected with reducer and sockets.

(2) M.S. pipe assembly having 350 mm Ø casing or housing pipe, with 200 mm Ø blind and slotted pipes connected vertically with 350 mm to 200 mm Ø reducer and sockets for 200 mm Ø pipes.

(3) A.C.C. pipe assembly of 250 mm Ø throughout the length (i.e. without any reducer) including casing or housing, blind and slotted pipes with horizontal slots.

The depth of the housing pipe adopted ; has followed roughly the following relationship:

Depth of housing pipe in feet = Depth to piezometric level in feet + 10R

Where R varied from 4.2 to 10.0 ft. in different years in the area.

The value of R increased with the passage of time. In 1955 it was 4.2 to 4.9 feet while in 1974-75 it was kept as 10 feet.

3.3 AQUIFER CHARACTERISTICS:

As the sand beds are generally lenticular and there are rapid alterations and gradations between granular and clayey horizoms, aquifer thickness ranges from a few meters to several tens of meters within a distance of a few kilometers. The near surface ground water is generally unconfined while deeper aquifers commonly contain water in confined condition in the study area.

If the confined sand is much more permeable than the confined clay or silt layer above it, (as this condition apparently is fulfilled in the present case), the leakage can be considered as vertical in the semiconfining layer and horizontal in the confined aquifers(Chaturvedi and Pathak 1970).

The formation constants i.e. the coefficients of permeability, transmissibility, storage and leakage describe the hydraulic characteristics of the aquifer. To study performance of the aquifer and to determine the formation constants, no data were available for the study area. However, data of pumping-tests conducted at sites in the nearby area namely Ujh Mungeri and Raghopur of

district Varanasi were available (Hasan et.al. 1974). The Ujh Mungeri (26, Bhadohigroup) and Raghopur (80 Bhadohigroup) wells were pumped for 347 and 425 minutes at a steady discharge of 2.15 m^3/minute (567 USGPM) and 3.69 m^3/minute (975 USGPM) respectively and the reduction of water levels were recorded in observation wells at **different time.** The observation wells for Ujh Mungeri pumping well and for Raghopur pumping well were situated at distances 56.71 m (186') and 45.73m (150') from the pumping wells respectively. The recovery of water levels were further recorded in the both observation wells, at different times, as 270 and 220 minutes. These both sides are situated north of river Ganga. The geological cross sections of pumping and observation wells are shown in Fig. 17 . The test data are given in Tables 5 and 6. The coefficients of transmissibility, storage, and leakage were computed by type curve method.

Using values of tables 5 and 6 two data curves were prepared by plotting value of draw-down 's' vs time t. These data curves were superimposed on type curves and the following match point coordinates were obtained. For case I (Table 5), see Fig. 18.

$$(1) \quad W\left(u, \frac{r}{B}\right) = 1.0$$

$$(2) \quad \frac{1}{u} = 10.0$$

TABLE 5

PUMP TEST AT UJH MUNGERI

Name of Pumping Well: Ujh Mungeri (reconstructed)	No. and Group 26 BG (Bhodohi Group)
Location on Toposheet 63 K (GSI):	Longitude 82°19' East and Latitude 25°19' North
Tehsil:	Gyanpur
District:	Varanasi

Discharge Q = 2.15 m^3/minute (567 USGPM)

Observation Well: Old Failed and Abandoned STW existed nearby

Distance between Pumping and Observation-well: r = 56.71 m(186')

Depth of Water below Ground Level : 6.52 m (21.374')

Lithological log and total depth of STW 26 BG and Observation well: As shown in Fig. 17(a)

(A) Observation During Pumping:

S.No.	Time (t) since Pumping Started	Water Level in Feet	Draw-down in Feet	Draw-down in Meters
1	2	3	4	5
1	1	21.374	0.000	0.000
2	3	21.395	0.021	0.006
3	5	21.417	0.043	0.013
4	8	21.437	0.063	0.019
5	9	21.450	0.084	0.026
6	10	21.500	0.126	0.038
7	11	21.520	0.144	0.044
8	14	21.562	0.188	0.057
9	16	21.583	0.209	0.064
10	18	21.603	0.229	0.070

Contd....

Table 5 contd....

1	2	3	4	5
11	20	21.624	0.250	0.076
12	25	21.666	0.292	0.089
13	30	21.707	0.333	0.102
14	35	21.728	0.354	0.108
15	40	21.770	0.396	0.121
16	50	21.812	0.438	0.134
17	60	21.833	0.459	0.140
18	70	21.853	0.479	0.146
19	80	21.874	0.500	0.152
20	90	21.875	0.521	0.159
21	105	21.927	0.553	0.169
22	165	22.000	0.626	0.191
23	310	22.042	0.688	0.210
24	347	22.062	0.688	0.210
		Pump stopped due to Electric failure		

(B) Observation During Recouperation:

Sl.No.	Time (t') in Minutes since pumping stopped	Time (t) in Minutes since pumping started	Residual Drawdown		Ratio t/t'
			Feet	Meter	
1	2	3	4	5	6
1	1	348	0.688	0.210	348.0
2	2	349	0.688	0.210	174.5
3	3	350	0.661	0.202	116.7

Contd....

Table 5 contd....

1	2	3	4	5	6
4	5	352	0.646	0.197	70.4
5	8	355	0.594	0.181	44.3
6	13	360	0.553	0.169	27.7
7	17	363	0.500	0.152	21.3
8	22	369	0.459	0.140	16.8
9	27	374	0.417	0.127	13.9
10	32	379	0.376	0.115	11.8
11	40	387	0.333	0.102	9.7
12	50	397	0.314	0.096	7.9
13	60	407	0.217	0.066	6.8
14	70	417	0.229	0.070	6.0
15	80	427	0.209	0.064	5.3
16	100	447	0.188	0.057	4.5
17	120	467	0.167	0.051	3.9
18	150	497	0.167	0.051	3.3
19	180	527	0.126	0.038	2.9
20	240	587	0.105	0.032	2.4
21	270	617	0.084	0.026	2.3

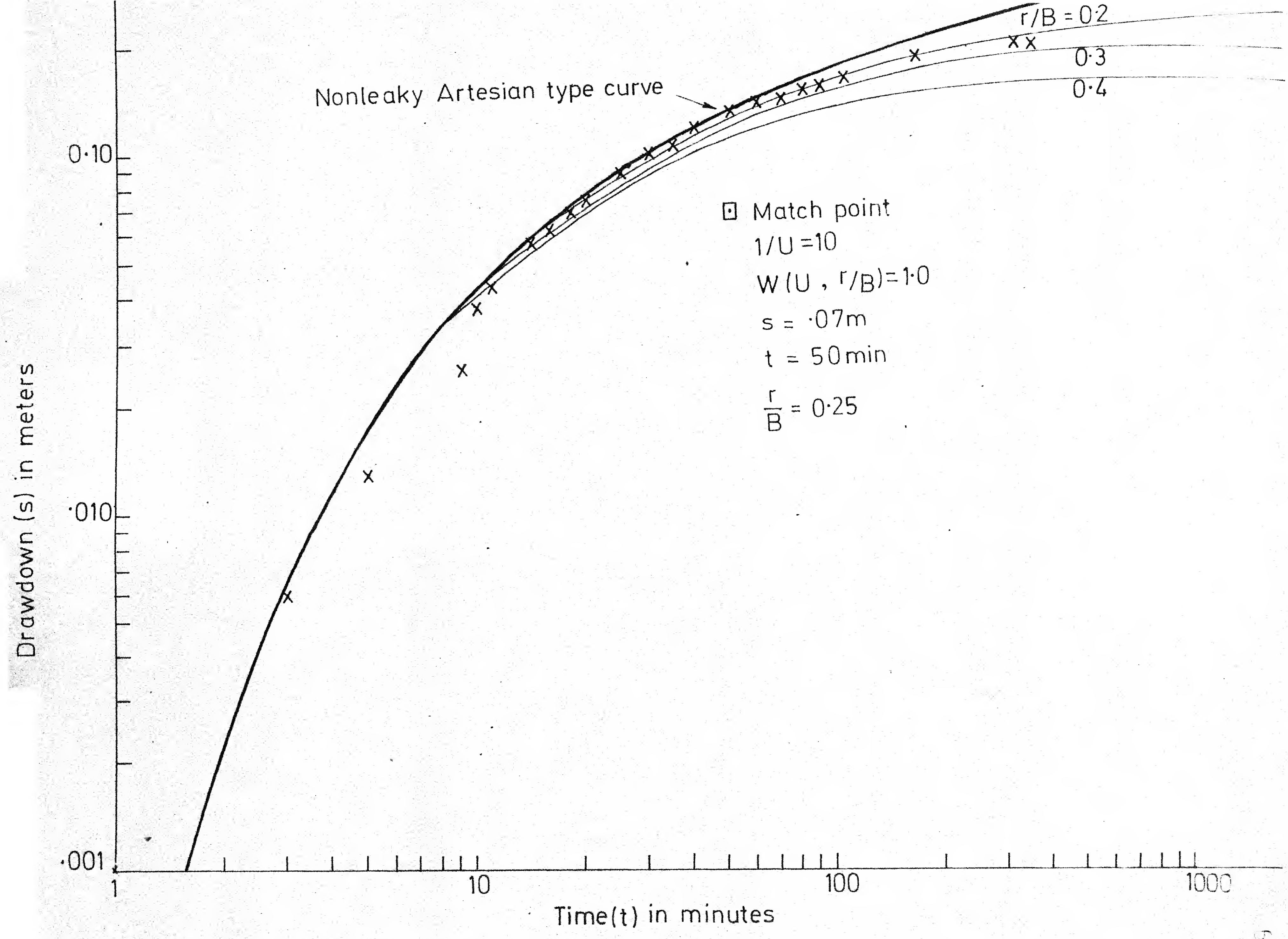


FIG.18 PUMP TEST AT UJH MUNGERI T. GYANPUR (VARANASI)

(3) s = 0.07 m

(4) t = 50.00 minutes

(5) $\frac{r}{B}$ = 0.25

The following equations are used for calculating the aquifer parameters.

$$s = \frac{Q}{4\pi T} W\left(u, \frac{r}{B}\right) \qquad (1)$$

$$u = \frac{r^2 S}{4 T t} \qquad (2)$$

$$\frac{r}{B} = \frac{r}{\sqrt{T/\frac{k'}{b'}}} = \frac{r}{\sqrt{\frac{kb\,b'}{k'}}} \qquad (3)$$

where s = draw down in meter,

Q = discharge in m^3/minute

T = transmissibility coefficient in m^2/minute

S = coefficient of storage

r = distance from pumping well to observation well in meters

t = time of draw down in minutes

u = variable of integration

$W(u, \frac{r}{B})$ = well function for leaky artesian aquifer with fully penetrating wells without water released from storage in aquitard and constant discharge condition.

B = a constant known as leakage factor

$B^2 = \dfrac{T}{k'/b'}$ = ratio of transmissibility and leakage coefficients,

k'/b' = leakance or leakage factor or coefficient of leakage in $sec.^{-1}$ or day^{-1}

k = coefficient of permeability in m/day

k' = vertical permeability of the confining layer in m/day

b = saturated thickness of aquifers in meters

b' = thickness of the confining layer or aquaitard in meters.

Using $Q = 2.15\ m^3/minute$

$r = 56.71$ meters and the above match point

coordinates we get:

(i) $$T = \frac{Q}{4\pi s} W\left(u, \frac{r}{B}\right) \qquad (4)$$

$$= \frac{2.15 \times 1}{4\pi \times 0.07}$$

$= 2.445\ m^3/minute/meter$ or $m^2/minute$

$= 3521.38\ m^2/day = 3521\ m^2/day$ (say)

(ii) $$S = \frac{4Tt}{\frac{1}{u} r^2} \qquad \text{where } r^2 = 3216\ m^2 \text{(say)} \qquad (5)$$

$$= \frac{4 \times 2.445 \times 50}{10 \times 3216}$$

$= 0.0152$

$S = 1.52 \times 10^{-2}$

$S = 1.5 \times 10^{-2}$ (say)

(iii) $\frac{r}{B} = 0.25$ (6)

or $B = \frac{56.71}{0.25}$

$= 226.84$

$B^2 = 51456.39$

$$\frac{k'}{b'} = \frac{T}{B^2} \qquad (7)$$

$$= \frac{3521.38}{51456.39} \quad (\text{ per day })$$

$$= 0.0684 \text{ day}^{-1} \quad \text{or } 0.07 \text{ day}^{-1} \text{ (say)}$$

$$= 7 \times 10^{-7} \text{ sec.}^{-1}$$

Hence leakance ,

$$= \frac{k'}{b'} = 7 \times 10^{-7} \text{ sec.}^{-1}$$

Case II (Table 6) see Fig. 19:

The following match point coordinates were obtained. Match point coordinates are :

(1) $W\left(u, \frac{r}{B}\right) = 2.0$

(2) $\frac{1}{u} = 200.0$

(3) $s = 0.4$ m

(4) $t = 110.00$ minutes

(5) $\frac{r}{B} = 0.17$

TABLE 6

PUMP TEST AT RAGHOPUR

Name of Pumping Well: Raghopur(reconstructed) — No. and Group 80 BG (Bhodohi Group)

Location on Toposheet 63 K (GSI): Longitude 82°35' East and Latitude 25°21' North

Tehsil: Gyanpur

District: Varanasi

Discharge Q = 3.69 m^3/minute (975 USGPM)

Observation Well: Old Failed and Abandoned STW existed nearby

Distance between pumping and observation well: r = 45.73m (150')

Depth of Water below ground level : 8.98 m (29.458')

Lithological log and total depth of STW 80 BG and observation well: As shown in Fig. 17(b)

(A) Observation During Pumping:

S.No.	Time (t) since Pumping Started	Water Level in Feet	Draw-down in Feet	Draw-down in Meters
1	2	3	4	5
1	1	29.791	0.333	0.102
2	2	30.083	0.625	0.157
3	3	30.333	0.875	0.267
4	4	30.458	1.060	0.323
5	5	30.562	1.104	0.337
6	6	30.666	1.208	0.368
7	7	30.750	1.292	0.394
8	8	30.812	1.354	0.413
9	9	30.853	1.395	0.425

Contd......

Table 6 contd...

1	2	3	4	5
10	10	30.917	1.459	0.445
11	12	31.000	1.542	0.470
12	14	31.103	1.645	0.502
13	16	31.167	1.709	0.521
14	18	31.208	1.750	0.534
15	20	31.270	1.812	0.552
16	25	31.353	1.895	0.578
17	30	31.437	1.979	0.603
18	35	31.500	2.042	0.623
19	40	31.451	2.083	0.635
20	50	31.583	2.125	0.698
21	60	31.666	2.208	0.673
22	70	31.707	2.249	0.686
23	80	31.750	2.292	0.699
24	100	31.791	2.333	0.711
25	120	31.874	2.416	0.737
26	140	31.874	2.416	0.737
27	180	31.970	2.512	0.766
28	220	32.000	2.542	0.775
29	260	32.020	2.562	0.781
30	320	32.020	2.562	0.781
31	380	32.020	2.562	0.781
32	425	32.020	2.562	0.781

Contd.......

Table 6 contd....

(B) Observation During Recouperation:

Sl.No.	Time(t') in Minutes since pumping stopped	Time(t) in Minutes since pumping started	Residual Drawdown		Ratio t/t'
			Feet	Meter	
1	2	3	4	5	6
1	1	426	2.292	0.699	426.0
2	2	427	2.042	0.623	213.5
3	3	428	1.792	0.546	142.7
4	4	429	1.375	0.419	107.3
5	5	430	1.292	0.394	86.0
6	6	431	1.208	0.368	71.8
7	7	432	1.125	0.343	61.7
8	8	433	1.042	0.318	54.1
9	10	435	0.958	0.292	43.5
10	12	437	0.913	0.278	36.4
11	14	239	0.875	0.267	31.4
12	16	441	0.833	0.254	27.6
13	20	445	0.708	0.216	22.3
14	25	450	0.625	0.191	18.0
15	30	455	0.542	0.165	15.2
16	40	465	0.458	0.140	11.6
17	50	475	0.375	0.114	9.5
18	60	485	0.333	0.102	8.1
19	80	505	0.208	0.063	6.3
20	100	525	0.166	0.051	5.25
21	130	555	0.103	0.031	4.3
22	160	585	0.083	0.025	3.7
23	220	645	0.062	0.019	2.93

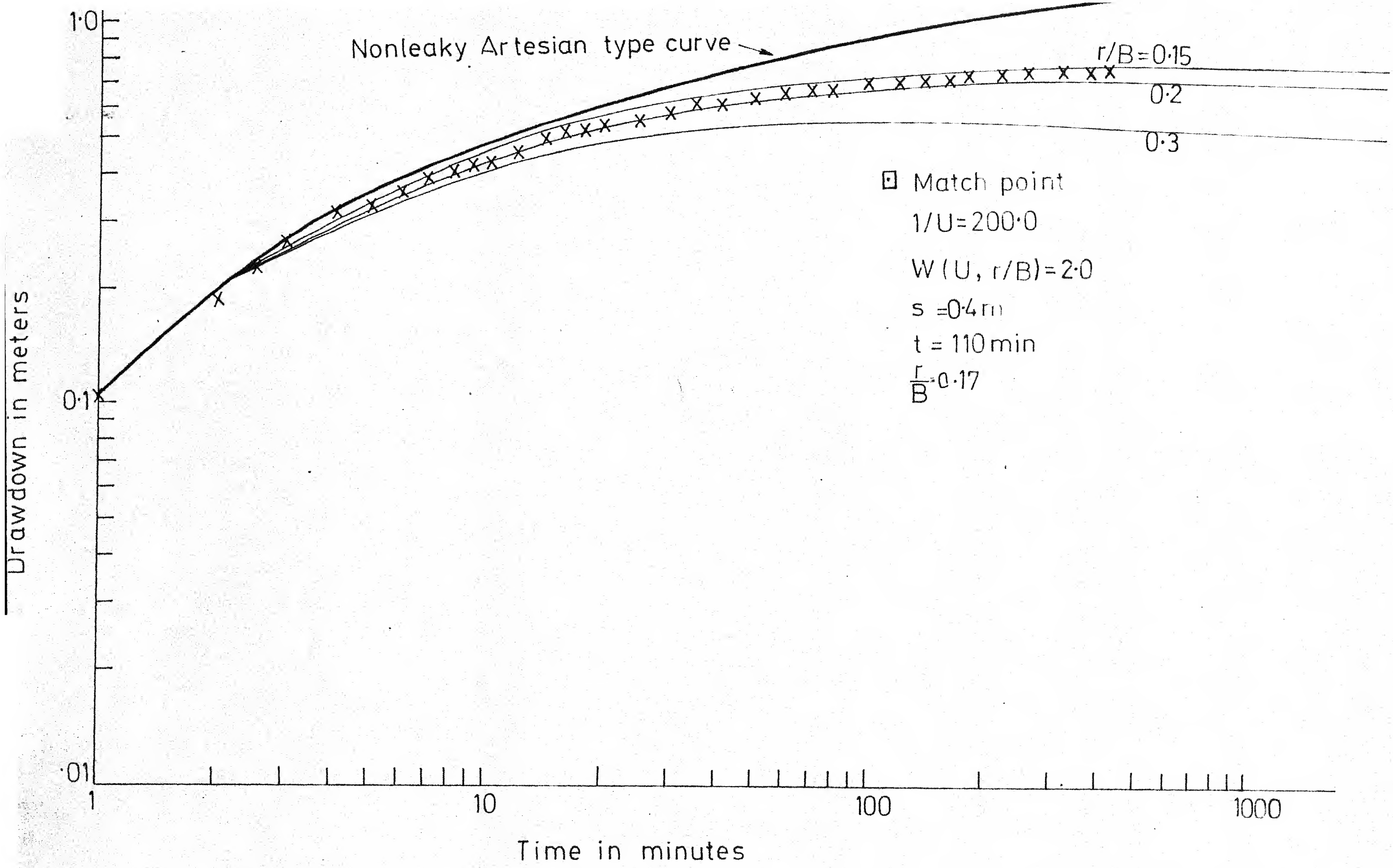


FIG.19 PUMP TEST DATA AT RAGHOPUR T. GYANPUR (VARANASI)

Using $Q = 3.69\ m^3/\text{minutes}$

$r = 45.73$ meters

$r^2 = 2091.2\ m^2$ and the above match point coordinates we get:

(i) $$T = \frac{Q}{4\pi s} W\left(u, \frac{r}{B}\right)$$

$$T = \frac{3.69 \times 2}{4\pi \times 0.4} \qquad (8)$$

$$= 1.4676\ m^3/\text{minute}/m \quad \text{or } m^2/\text{minute}$$

$$= 2113.36\ m^2/\text{day} = 2113\ m^2/\text{day (say)}$$

(ii) $$S = \frac{4Tt}{\frac{1}{u} r^2}$$

$$S = \frac{4 \times 1.4676 \times 110}{200 \times 2091.2} \qquad (9)$$

$$= 0.00154$$

$$S = 1.54 \times 10^{-3} = 1.5 \times 10^{-3} \text{ (say)}$$

(iii) $$\frac{r}{B} = 0.17 \qquad (10)$$

$$B = \frac{45.73}{0.17}$$

$$= 269.0$$

$$\frac{k'}{b'} = \frac{T}{B^2}$$

$$= \frac{2113.36}{269 \times 269}$$

$$\frac{k'}{b'} = 0.0292 \ \text{day}^{-1} = 0.03 \ \text{day}^{-1} \ \text{(say)}$$

$$\frac{k'}{b'} = 3 \times 10^{-7} \ \text{sec.}^{-1}$$

3.3.1 RESULTS OF PUMPING TESTS:

From the study of the above tests on aquifers at two sites (i.e. Ujh Mungeri and Raghopur of district Varanasi) it may be seen that coefficients of transmissibility, storage and leakage varied from 2113.36 to 3521.38 m^2/day, 0.00152 to 0.0154 and 3×10^{-7} to 7×10^{-7} sec.$^{-1}$ respectively. Geological cross-sections of these sites are shown in Fig.17a and 17b respectively. The duration of the tests, conducted in the tube-wells are 347 and 425 minutes only, which is rather very short and hence the results obtained for T, S and leakance are not likely to be true representation of the aquifer characteristics of the area. Typically long duration tests of the order of several days should be conducted in the area under desired ideal conditions for evaluating the formation constants of the aquifer.

The water table depth in the study area is observed and recorded every month on selected open wells by the State Ground Water Investigation Organisation, Lucknow.

Piezometric level depth in each state tube-well is observed twice a year before arrival of the monsoon and just after it is over i.e. at the beginning of each of the two crops (Kharif and Rabi), by State Irrigation Tube-well Department. Maps showing the location of open masonry wells on which periodical observations of water table are recorded are shown in Figs. 1 and 2 and contour maps for showing water table depth in May 1976 is shown in Fig. 20. The contour maps showing depth to piezometric surface in state tube-wells in May 1959 and May 1976 are shown in Figs. 21 and 22 respectively. These figures shows that water table and piezometric level in the study area has moved down ward.

It has not been possible to ascertain, how accurate these data are. Ideally speaking, when observations are made on a state tube-well or open wells no water from the adjoining wells should be pumped out , so that there is no interference in the piezometric level and water table level of the observation well. It is very likely that this condition was not fulfilled while taking the observations at the sites.

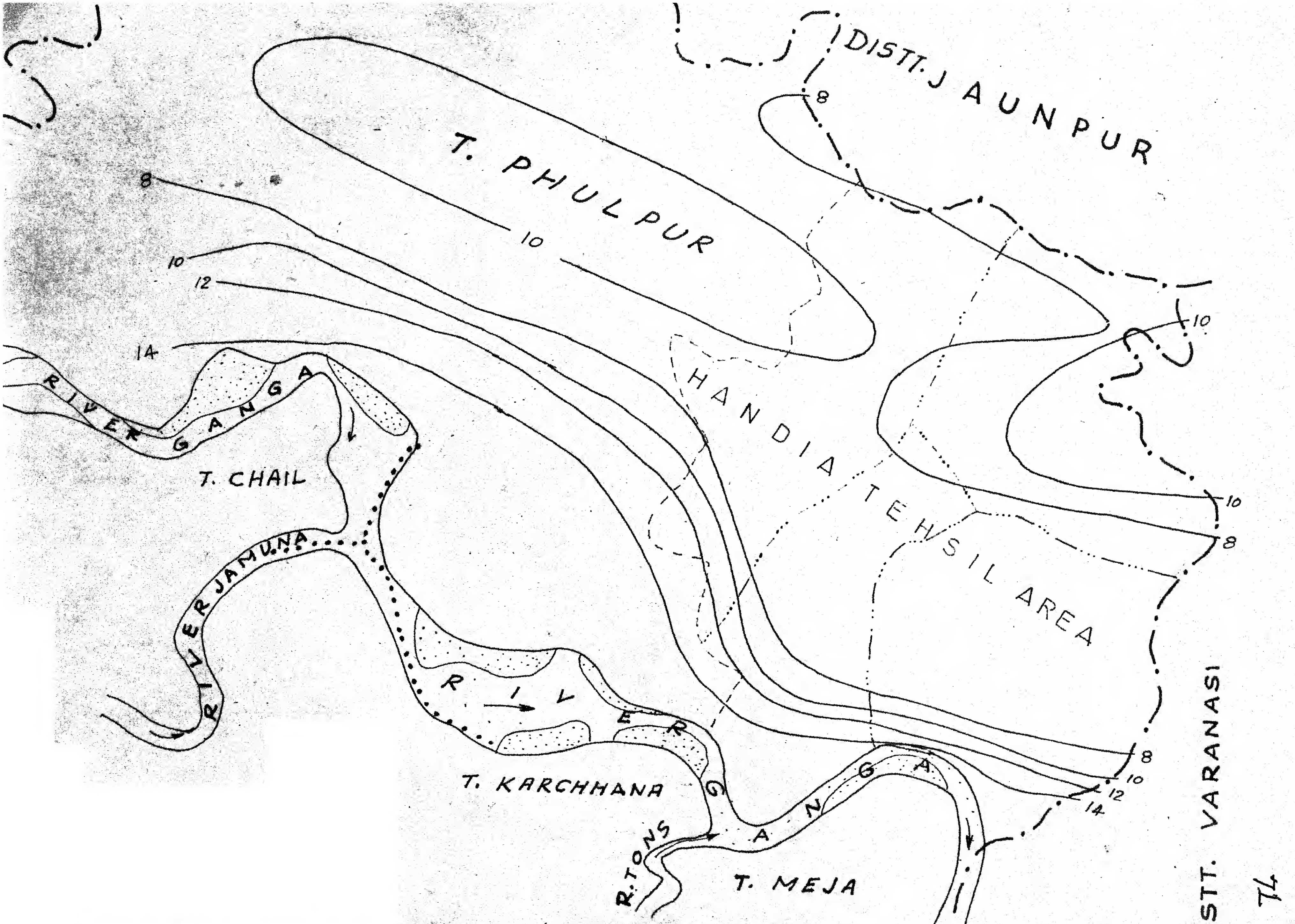
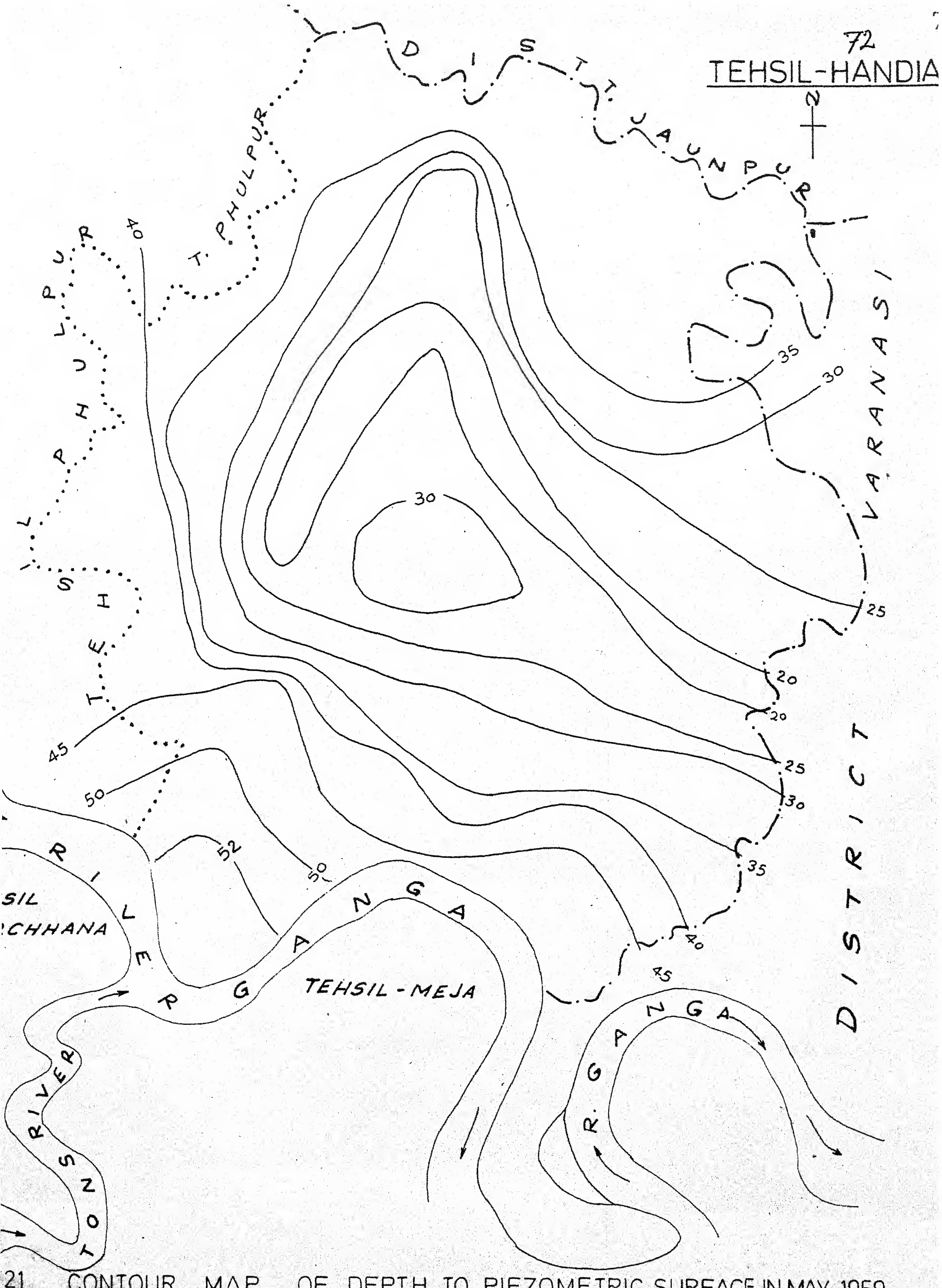
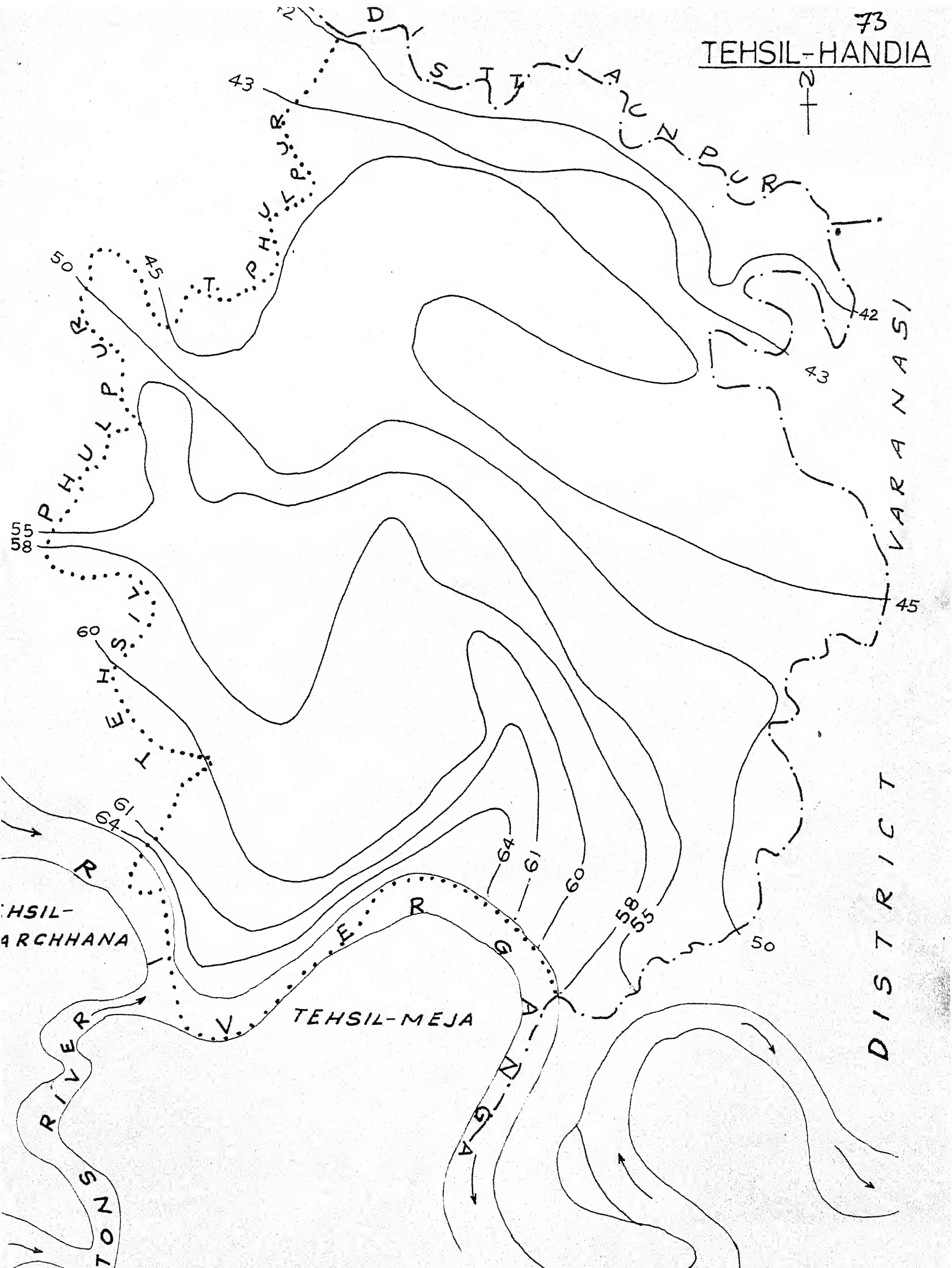


FIG.20 CONTOUR MAP OF DEPTH TO WATER TABLE IN MAY 1976 (in meters)



21 CONTOUR MAP OF DEPTH TO PIEZOMETRIC SURFACE IN MAY 1959



22 CONTOUR MAP OF DEPTH TO PIEZOMETRIC SURFACE IN MAY 1976 (IN

CHAPTER V

5.1 RESULTS, DISCUSSION AND CONCLUSION:

5.2 INTRODUCTION:

The response of aquifer to large scale pumping in Handia Tehsil is presented in this Chapter, The results are discussed under various assumed operating policies. As mentioned in Chapter IV, since the value of 'S' was determined by short duration pumping test, the effect of an increased 'S' on the aquifer response is also discussed.

5.3 STANDARD SET:

For purposes of comparison, the following parameters are used as the standard set.

$S = 0.015$

$T = 2985\ m^2/day$

$Q = 2446\ m^3/day$

No. of wells = 289

No. of Recharge Wells = None

No. of Seasons - two in a year namely $t_1 = 62.5$ days and $t_2 = 125$ days

Using the above values, we get the total amount of water lifted from the entire area in each season as 4418.0 hectare meters per season or 8836 hectare meters in a year. The

TABLE 7

COMMONLY USED MATHEMATICAL MODEL EQUATIONS

Sl.No.	Mathematical Model Equations used in metric system	Applied to
1.	$s = \frac{Q}{4\pi T} w(u)$ $u = \frac{r^2 S}{4Tt}$	Isotropic nonleaky artesian aquifer with fully penetrating wells and constant-discharge conditions
2.	$s = \frac{Q}{4\pi T}, W(u, \frac{r}{m}, \nu)$ $u = \frac{r^2 S}{4 T t}$ $\nu = \frac{n - m_d}{m}$	Isotropic nonleaky artesian aquifer with partially penetrating wells and constant discharge conditions
3.	$s = \frac{Q}{4\pi T} W(u, \frac{r}{B})$ $\frac{r}{B} = \frac{r}{\sqrt{T/(\frac{P'}{m'})}}$ $u = \frac{r^2 S}{4T t}$ $s = \frac{229 Q}{T} k_o(\frac{r}{B})$ (in American unit) or $s = \frac{Q}{2\pi T} K_o(\frac{r}{B})$	Isotropic leaky artesian aquifer with fully penetrating wells and constant discharge conditions without water released from storage in aquitard.

Contd....

Table 7 contd...

Sl.No.	Mathematical Model Equations used in metric systems	Applied to
4.	$s = \frac{Q}{4\pi T} W(u_{ay}, \frac{r}{D_t})$ $u_a = \frac{r^2 S}{4\ T\ t}$ $u_y = \frac{r^2 S_y}{4\ T\ t}$ $\frac{r}{D_t} = \frac{2.73\ r}{\sqrt{T/D_1\ S_y}}$ $D_i = \frac{(r/D_t)^2 (\frac{1}{u_y})}{4\ t}$	Isotropic water-table aquifer with fully penetrating wells and constant discharge conditions.

where,

s = drawdown in meters ,

Q = discharge in m^3/day

T = coefficient of transmissibility of aquifer in m^2/day

S = coefficient of storage of aquifer, fraction

r = distance from production well to observation point in meters

t = time after pumping started in days

m = saturated thickness of aquifer in meters

m_d = distance from top of aquifer to top of screen in meter

p' = coefficient of permeability of aquitard in m/day

m' = saturated thickness of aquitard in meters

Sy = specific yield of aquifer in meters

k_0 = Bessel function of the zeroth order and second kind.

$W(u)$, $W(u, r/B)$, $W(u, r/D_t)$, $W(u, r/B, \gamma)$ are well functions.

In applying the analytical methods mentioned above, the principle of super position is made use of . That is, since the approximate governing differential equation used in the simplified models is linear, the effects of pumping or recharge from several wells are superposed. If the number of wells operating in an aquifer is small, this addition can be done manually. If the number of wells is large then recourse is taken to digital computers.

Boundary conditions are usually taken into account in these analytical methods by the method of images. Figs. 23 and 24 shows the schemes that are used for simple geometries (Walton 1970).

As can be seen from the Figs. 23 and 24 , this method may result in a very large number of image wells, but it is not necessary to include image wells which are very far off from the point under consideration. A graphical technique is used in deciding the number of image wells, to

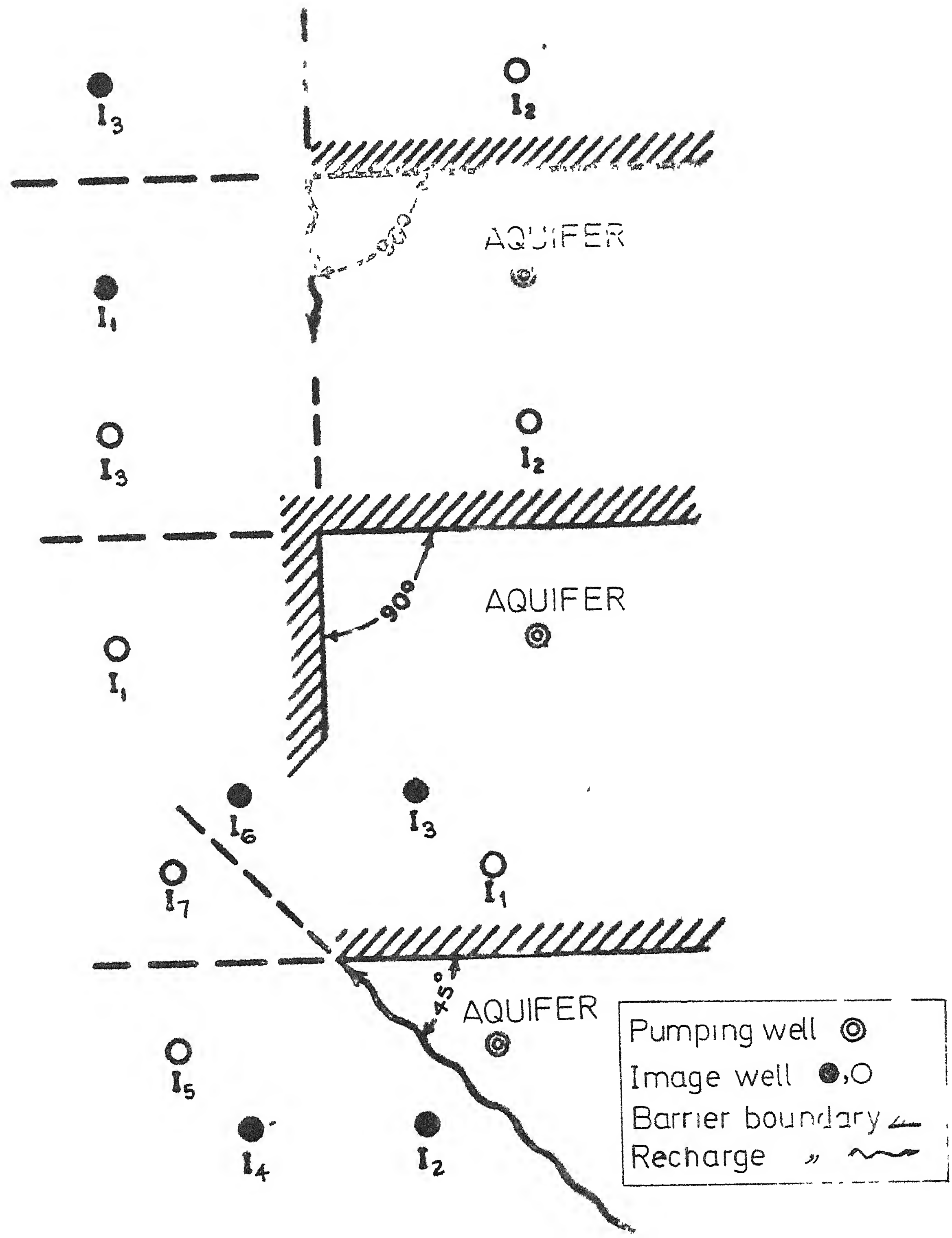


FIG 23 IMAGE WELL PATTERN FOR A QUADRANT AND A WEDGE

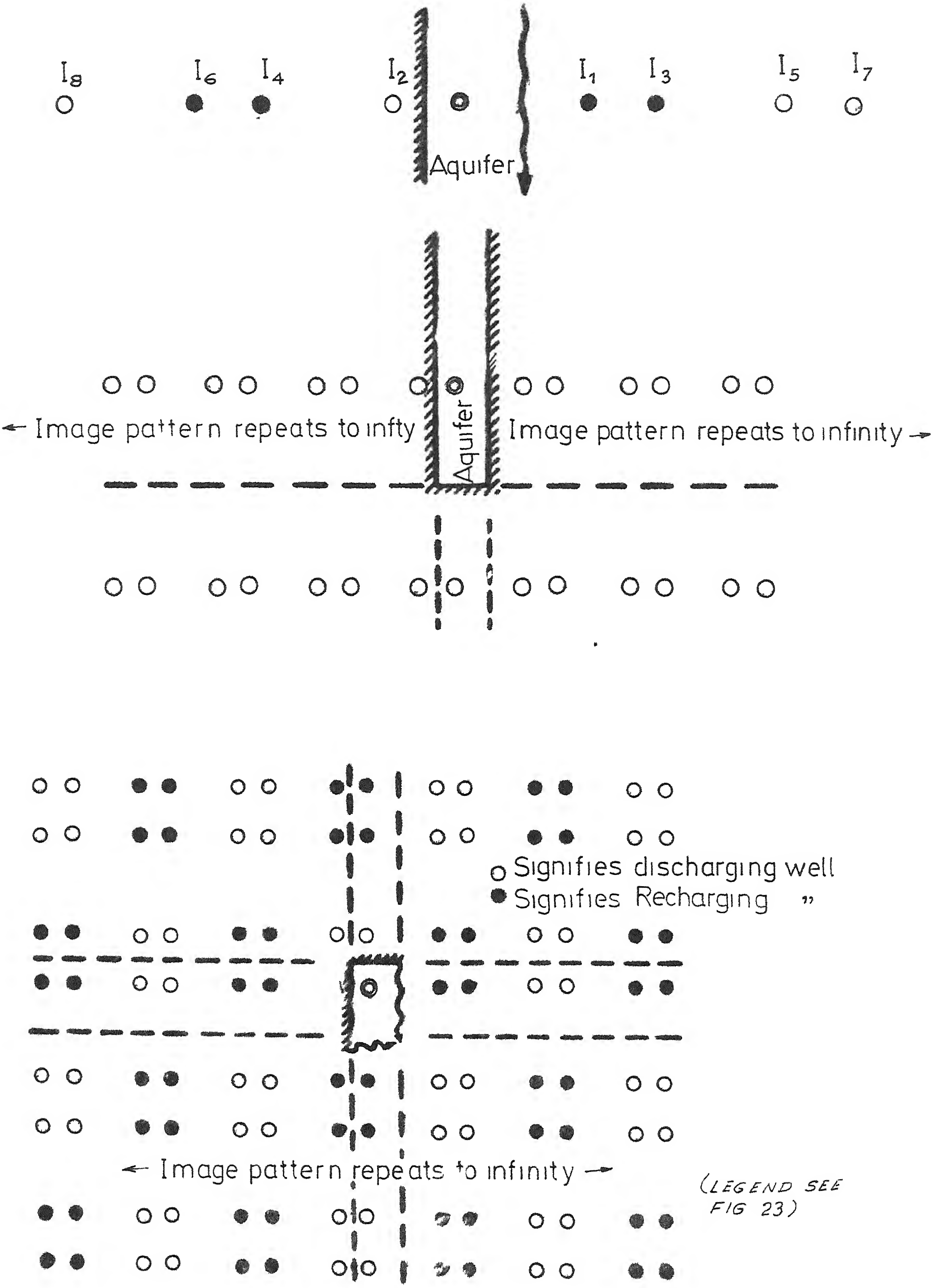


FIG 24 IMAGE WELL PATTERN FOR PARALLEL BOUNDARIES

be considered in a given problem (see Fig. 25). From these figures it can be seen that only those numbers of image wells need to be taken which come within an $r = 600$ m for the following parameters: $T = 3521\ m^2/day$; $S = 1.5 \times 10^{-2}$; $Q = 1.344\ m^3/sec.$; or $1.16 \times 10^5\ m^3/day$; $r/B = 0.25$ and $t = 146$ days.

This technique is applied as a first step on the basis of a simplified model adopted for the Handia area The area is bounded by Ganga on the south . The length and breadth of the area are 28 km. and 27.8 km. respectively. The area is divided into nine cells and the wells located in each cell are considered to be concentrated at the centre of the cell. The number of image wells in this case comes out to be nine. Assuming that there are in all 288 state tube-wells in this area as of 1976-77 each cell represents a well field of 32 state tube-wells. Assuming a capacity of each of the tube-well as 0.042 cumec (1.5 cusec) the 32 tube-wells will have a pumping capacity of 1.344 cumec. The response of the piezometric surface due to simultaneous pumping of all the wells comes out to be about 60 meters at each of the pumping centers. This large drawdown is because the well discharges in a cell are concentrated at centre of the cell. If, however, the total discharge from a cell is assumed to be

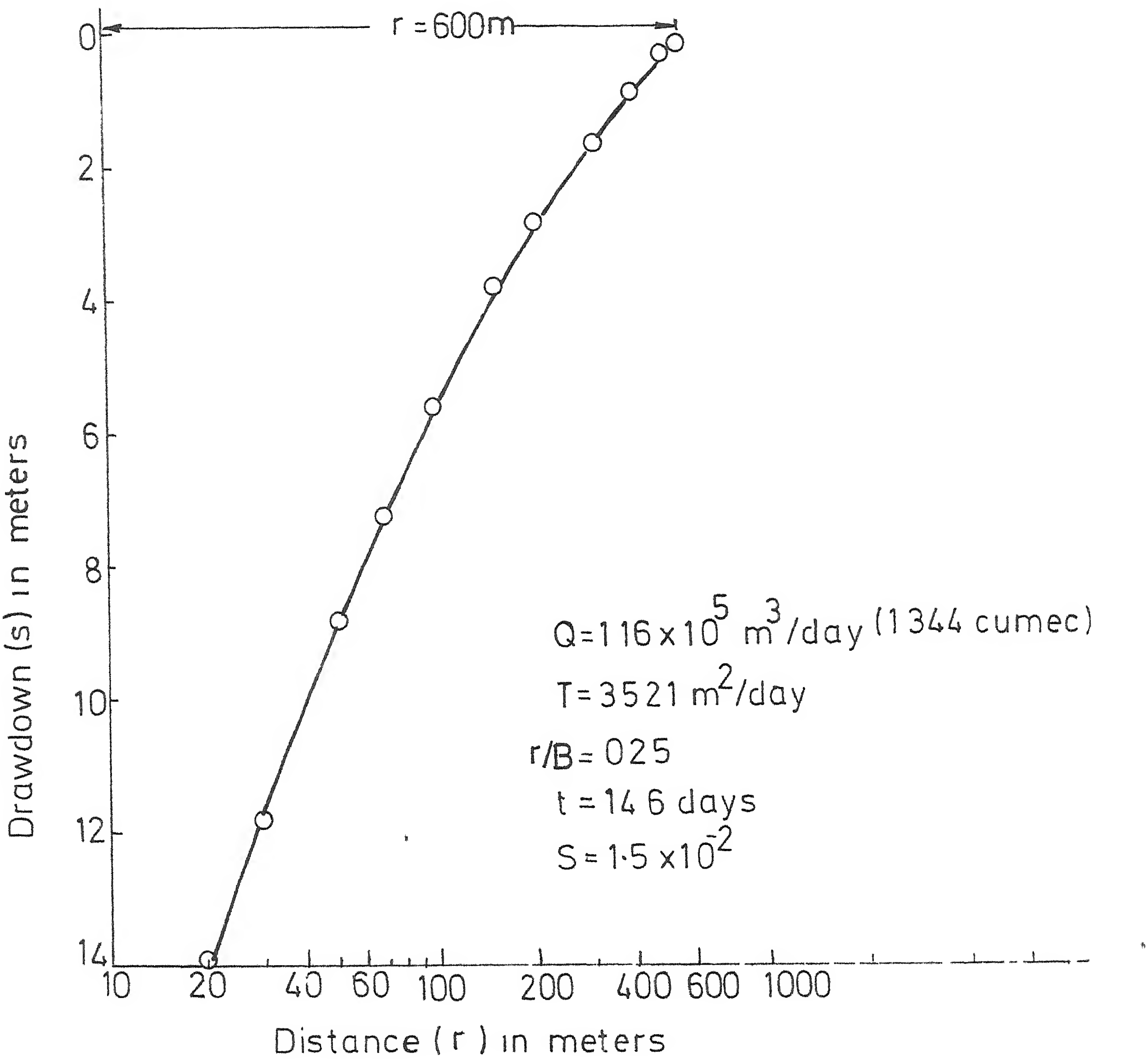


FIG 2 5 DISTANCE-DRAWDOWN GRAPH

uniformly distributed over the cell then the drawdown comes out to be about 5 meters. The actual drawdown due to pumping of 32 state tube-wells in a cell will be between these two values.

In order to get a more accurate representation of the aquifer response a digital model described in next section is used.

4.3 DIGITAL MODEL:

As the number of wells pumping from an aquifer increases, response calculation manually becomes tedious. Digital models are used in such cases. In applying a digital model, the aquifer is first descretized by superposing a grid of horizontal and vertical lines. The intersection of the grid lines are termed as nodes.

The differential equation governing ground water flow in non-homogeneous, isotropic aquifer in two dimensions is given by:

$$T \frac{\delta}{\delta x} \left(\frac{\delta h}{\delta x} \right) + T \frac{\delta}{\delta y} \left(\frac{\delta h}{\delta y} \right) = S \frac{\delta h}{\delta t} + Q \qquad (11)$$

where, T = transmissibility of the aquifer in the x and y direction in the horizontal plane,

h = storage coefficient

Q = net ground water withdrawl per unit area.

x and y = rectangular coordinates,

t = time coordinates.

This equation is then written for each node. The differentials δx and δy and δt are approximated by differences Δx, Δy, and Δt. The discretized model is a reasonable representation of the continuous system provided Δx, Δy are small compared to total area of the aquifer.

The difference equation for each node can be derived either from the differential equations given above or from physical considerations using Darcy's Law and Continuity Equations. The finite difference equation may be either implicit or explicit. In the implicit method the space derivatives are replaced by finite differences at the time at which the heads are to be calculated. This involves solving a set of simultaneous equations but the advantage in this method is that it is unconditionally stable regardless of the size of the time increment.

Using a implicit finite difference scheme for the present problem, we get the following equations: (Prickett, 1975)

$$T_{i-1,j}\left(\frac{h_{i-1,j}-h_{i,j}}{\Delta x^2}\right) + T_{i,j}\left(\frac{h_{i+1,j}-h_{i,j}}{\Delta x^2}\right) + T_{i,j}\left(\frac{h_{i,j+1}-h_{i,j}}{\Delta y^2}\right) + T_{i,j-1}\left(\frac{h_{i,j-1}-h_{i,j}}{\Delta y^2}\right) = S_{i,j}\left(\frac{h_{i,j}-h\emptyset_{i,j}}{\Delta t}\right) + \frac{Q_{i,j}}{\Delta x\,\Delta y} \qquad (12)$$

where,

Δx , Δy = finite difference grid size in the x and y directions,

i, j = column and row numbers of a node (i, j)

Δt = time increment elapsed since last calculation of heads

$h\phi_{i,j}$ = calculated head at the present time increment at the node (i, j)

$T_{i,j}$ = transmissibility of the branches between nodes (i, j) and $(i+1, j)$, and between nodes (i, j) and $(i, j+1)$. The transmissibility of a branch between any two nodes is taken to be the average of the values at those two nodes,

$S_{i,j}$ = storage coefficient at the node (i, j),

$Q_{i,j}$ = not withdrawl rate from the vectors value of the aquifer centered at i, j.

The equation is written for each node which results in a set of simultaneous equations.

There are many methods available for solving a set of simultaneous equations. Some of these methods are the successive over relaxation method, alternating direction implicit method, and others. The simplest method is the successive over relaxation method, but it is adequate only for small size problems. In the present problem a modified

version of iterative alternating direction implicit method given by Prickett , 1975 is used.

A computer programme written by Mr. T.A. Prickett and C.G. Lonquist of Illinois State Water Survey, Urbana, Illinois was modified and employed for the problems encountered in the Handia Tehsil. This programme utilises the modified iterative alterating direction implicit algorithum mentioned above. Annexture 3 gives the computer programme.

In the first instance the number of wells operating in the aquifer systems tapped by state tube-wells was taken to be 289 which is roughly the number that existed in 1976-77 in the study area. A grid work of 17 x 17 lines giving total number of nodes of 289 covering an area of 259.2 square miles (165894 acres or, 663.5 sq. kilometers) was used. This would mean that each nodal point represents an area of roughly 2290000 sq. meters. A well is located at each node giving total number of 289 state tube-wells. The distance between one well to another well roughly comes out to be 1525 meters in the model.

The annual average number of working hours for each tube-well is taken to be either 3000 hours (on the basis of the 'Report on the project estimate for the construction of 239 state tube-wells of Third Five Year Plan in Uttar Pradesh'),

or 3500 hours (on the basis of the 'Report on the project estimate for the construction of 2500 state tube-wells in Uttar Pradesh'), and capacity of each well is taken as 0.042 cumec (1.5 cusec) as provided in the project proposals mentioned above.

The year is devided into two seasons. In some runs of the model, each season is taken to be of equal length. of period. In some other runs the seasons are of unequal length. When the average annual number of running hours per state tube-wells is taken as 3000 in a year, the Rabi working or running hours are taken as 2300 hours and the Kharif as 700 hours. When the average total number of working or running hours per state tube-well is taken 3500 in a year, the Rabi pumpage is taken as 2500 hours and that of Kharif is as 1000 hours.

The transmissibility coefficient (T) used in the model is 2985 m^2/day. Two values of the storage coefficient(S) were used namely 0.015 and 0.10. It is seen from Chapter III that the short duration pumping tests gave only 'S' values of 0.015 and 0.0015. It is believed that these values are rather low. If a longer duration pumping test is conducted a higher value of S may be obtained because of the connectivity of the various aquifers. Therefore , in the model a higher

value of S namely $S = 0.1$ is also used in addition to the value of $S = 0.015$.

The model is also tested for a possible increase in the pumpage from the aquifer. A scheme of 676 wells against the present 289 wells is considered and its effect on the aquifer is tested.

As reported in Chapter III, there seems to be some evidence and also experienced by the author during his posting in the study area in year 1968-71, the piezometric surface to be going down every year. If this is true, then it is necessary that the aquifer should be properly managed, such that no long term depletion of the piezometric surface occurs. One of the common methods of the management is that the aquifer is recharged artificially, when excess surface water is available in the basin. The type of recharging facility depends on many factors. In the present analysis water is artificially recharged at certain nodes of the model. In one run a line of recharge wells is used operating throughout the year. In another run six lines of recharged wells are used operating only during the Kharif season to see the response of the aquifer to this combined pumpage and artificial recharge operations. As already mentioned the type of recharging facility is not discussed in this report. The results of the model tested under different conditions are reported in the next chapter.

aquifer response due to this pumping is given in Fig. 26. The numbers of contour lines represents the draw-downs due to above pumping in feet. Table 8 gives the parameters used in various different simulation runs.

5.4 EFFECT OF CHANGE IN THE VALUE OF 'S':

If the value of 'S' is 0.1 instead of 0.015 then draw-down would be much less than those shown in Fig. 26. This can be seen from Fig. 28. It is therefore necessary that some long duration tests should be conducted in the area to get a proper value of 'S' to be used in the model.

This 'S' value can also be decided if we have historical data for a few years about the piezometric surface recorded properly.

5.5 EFFECT OF INCREASE IN THE RUNNING HOURS OF PUMPS:

It is obvious that if we increase the number of running hours there will be more draw-down. For instance, if instead of 3000 hours of pumping hours used in para 5.3, we used 3500 numbers of pumping hours, then pump will be lifting 5153 hectare meters per season or 10306 hectare meters during the whole of the year from the entire area The effect of this increased pumping hours on the aquifer is seen from Fig. 27. In this figure the value of S is taken as S = .015. If the S value is 0.1 then the draw-down will be less as before (See Fig. 29).

TABLE 8

VARIOUS PARAMETERS USED IN DIFFERENT SIMULATION RUNS

Sl.No.	Run Number	S	T m^2/day	Q m^3/day	t_1 in days	t_2 in days	Total Number of Wells running	Total No. wells used as recharge wells	Reference Fig. No.	Remark
1	2	3	4	5	6	7	8	9	10	11
1.	RUN1	0.015	2985	2446	83.5	167.0	289	None	-	
2.	RUN2	0.015	2985	3414	83.5	167.0	289	None	-	
3.	RUN3	0.015	2985	2446	62.5	125.0	289	None	26	Standard Set
4.	RUN4	0.015	2985	2446	72.9	145.8	289	None	27	
5.	RUN5	0.10	2985	2446	62.5	125.0	289	None	28	
6.	RUN6	0.10	2985	2446	72.9	145.8	289	None	29	
7.	* RUN7	0.015	2985	2446	62.5	125.0	272	17	30	
8.	* RUN8	0.015	2985	2446	72.9	145.8	272	17	31	
9.	RUN9	0.015	2985	2446	62.5	125.0	676	None	32	
10.	RUN10	0.015	2985	2446	72.9	145.8	676	None	33	
11.	** RUN11	0.015	2985	2446	30.0	126.0	187	102	34	

1. * 17 Nos. STWS' were converted as recharge well installed in a line capacity of duration of each recharging well was same as of state tube-wells. t_1, t_2 and Q will be same for discharge and recharge wells.

2. ** 17 x 6 = 102 nos of pumping wells were converted into recharging well and were placed middle of the study area.

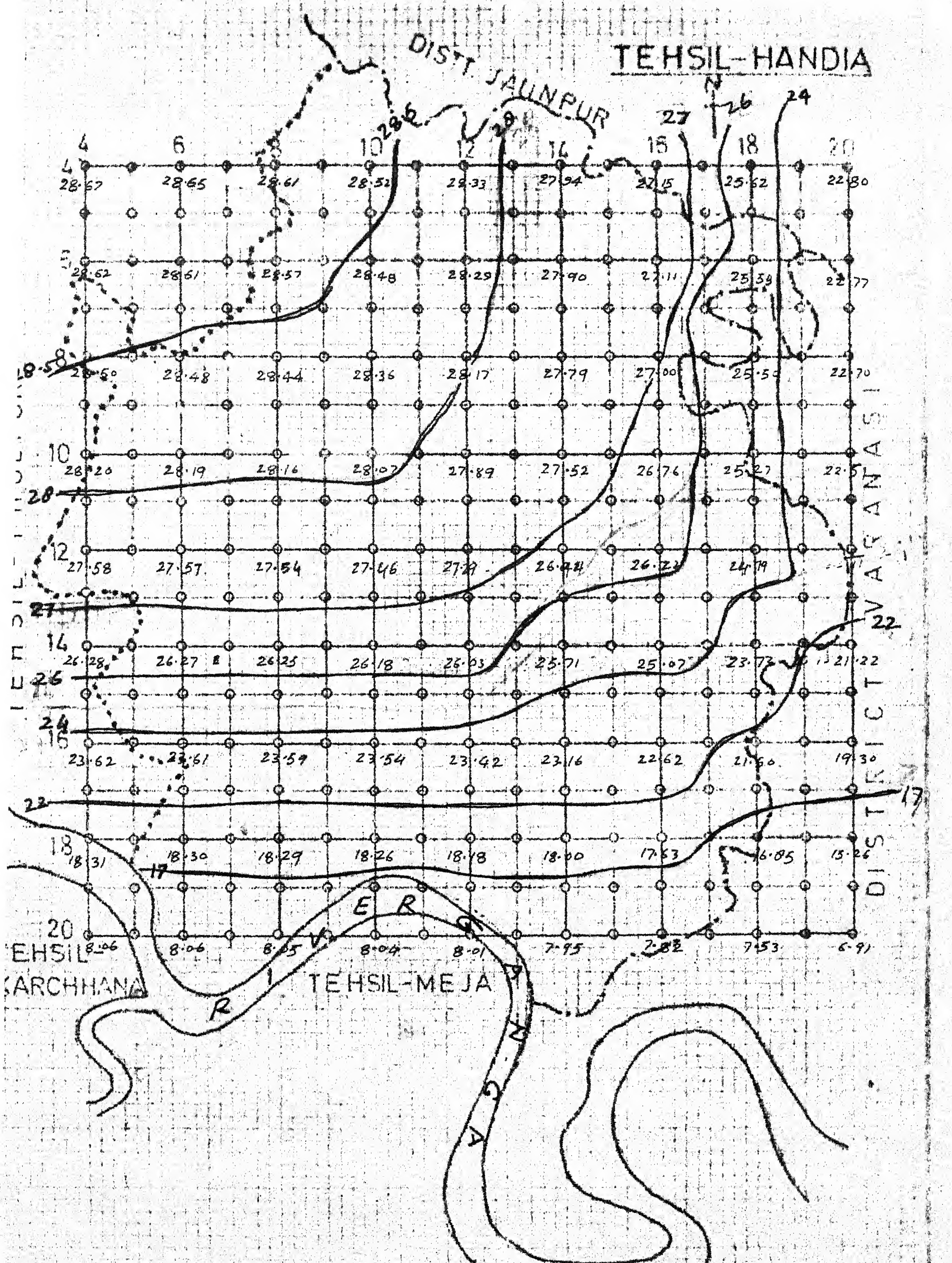


FIG 26 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT.)
RUN No. 3

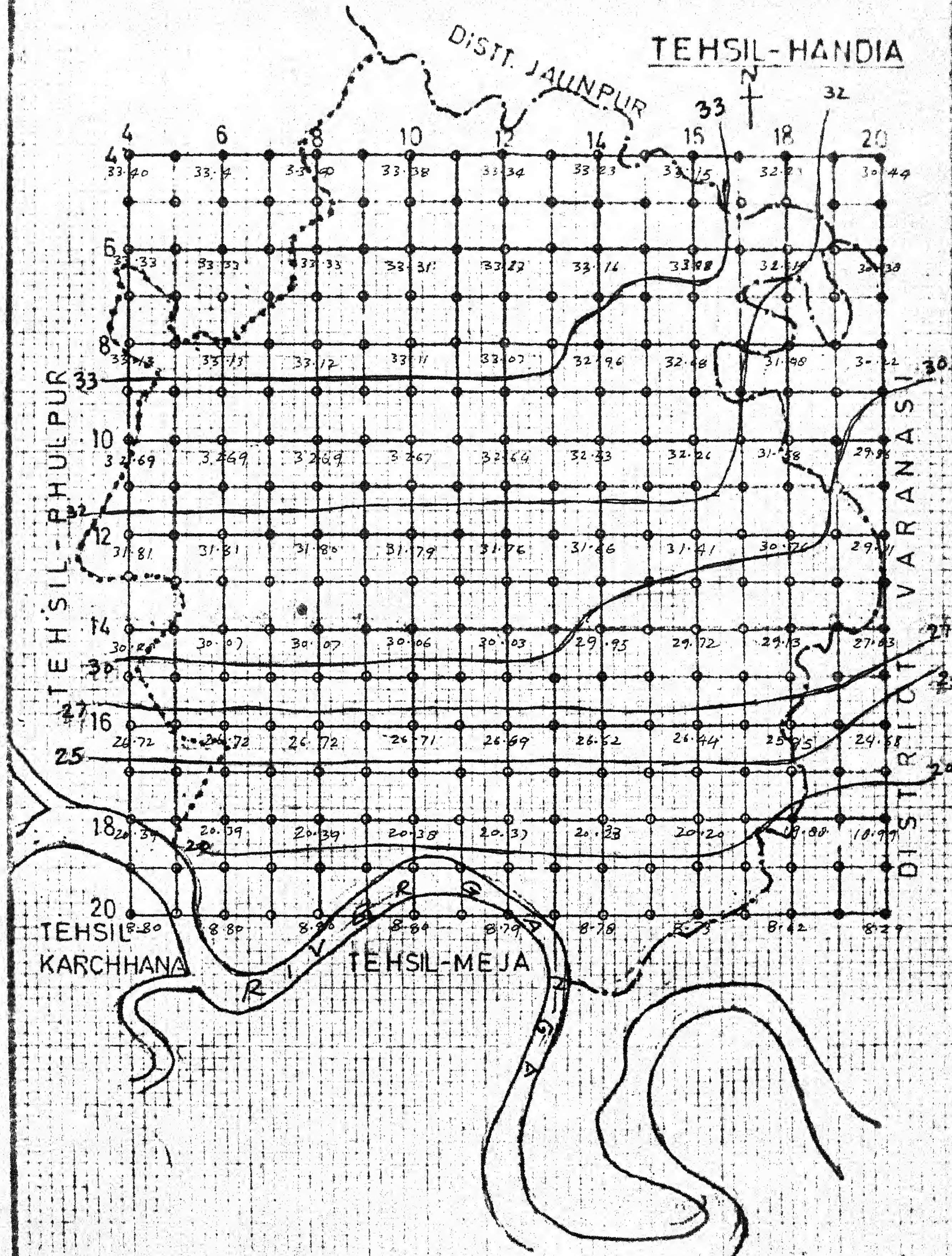


FIG.27 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES(IN FT)
RUN No.4

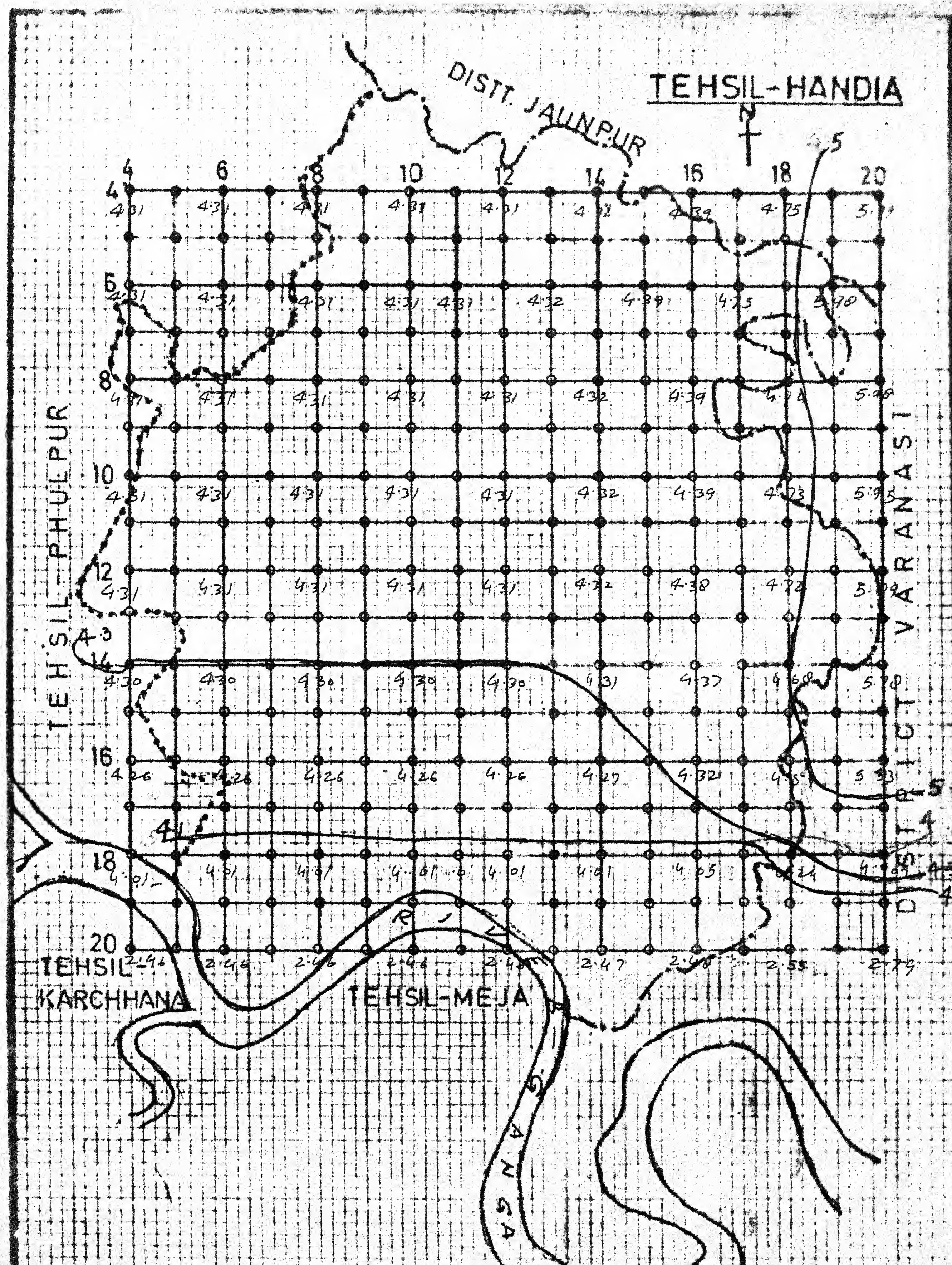


FIG.28 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT)
RUN No.5

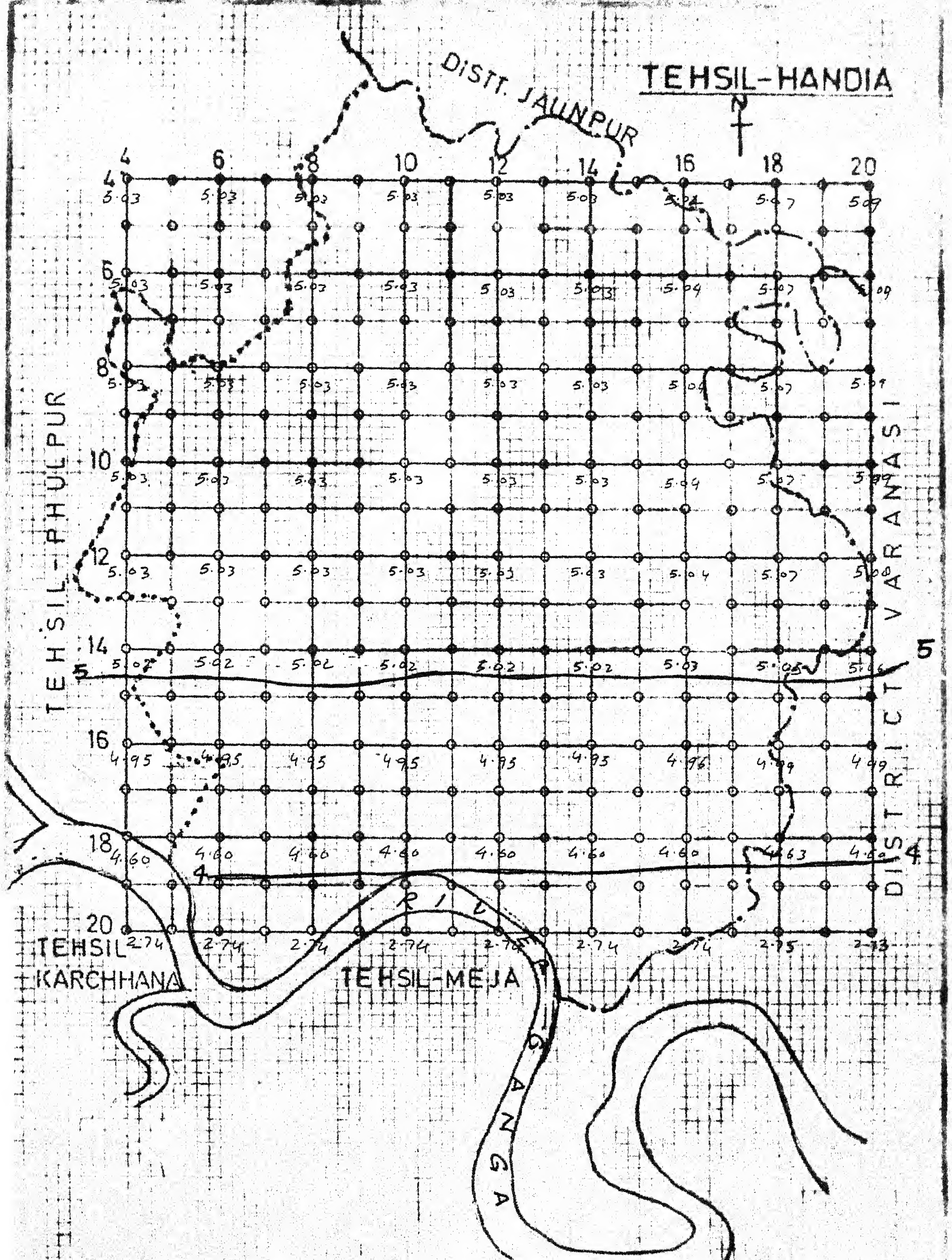


FIG. 29 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT)
RUN No. 6

where

s = additional draw-down or head decline to be added to the calculated value from pumped well node of the digital model, in feet.

T = Aquifer transmissivity in viscinity of pumped well in gallons/day per foot.

Q = Pumping rate of the well in **gpd** (gallons per day)

With this much of draw-down it is possible that many state tube-wells may go dry. It is therefore necessary to think in terms of artificial recharging when there is surplus water during the monsoon period.

5.7 EFFECT OF ARTIFICIAL RECHARGE:

In order to see effect of artificial recharge on the aquifer, a line of recharge wells consisting of 17 wells was put in the area. These recharge wells were assumed to run for the whole year simultaneously with the pumping wells. The capacity of each of these recharge wells was same as the pumping wells, namely 2446 m^3/day. It is also assumed that the same pumping well can be used as recharging well by reversible motors. The response of aquifer to such a recharge scheme is shown in Fig. 30 and 31.

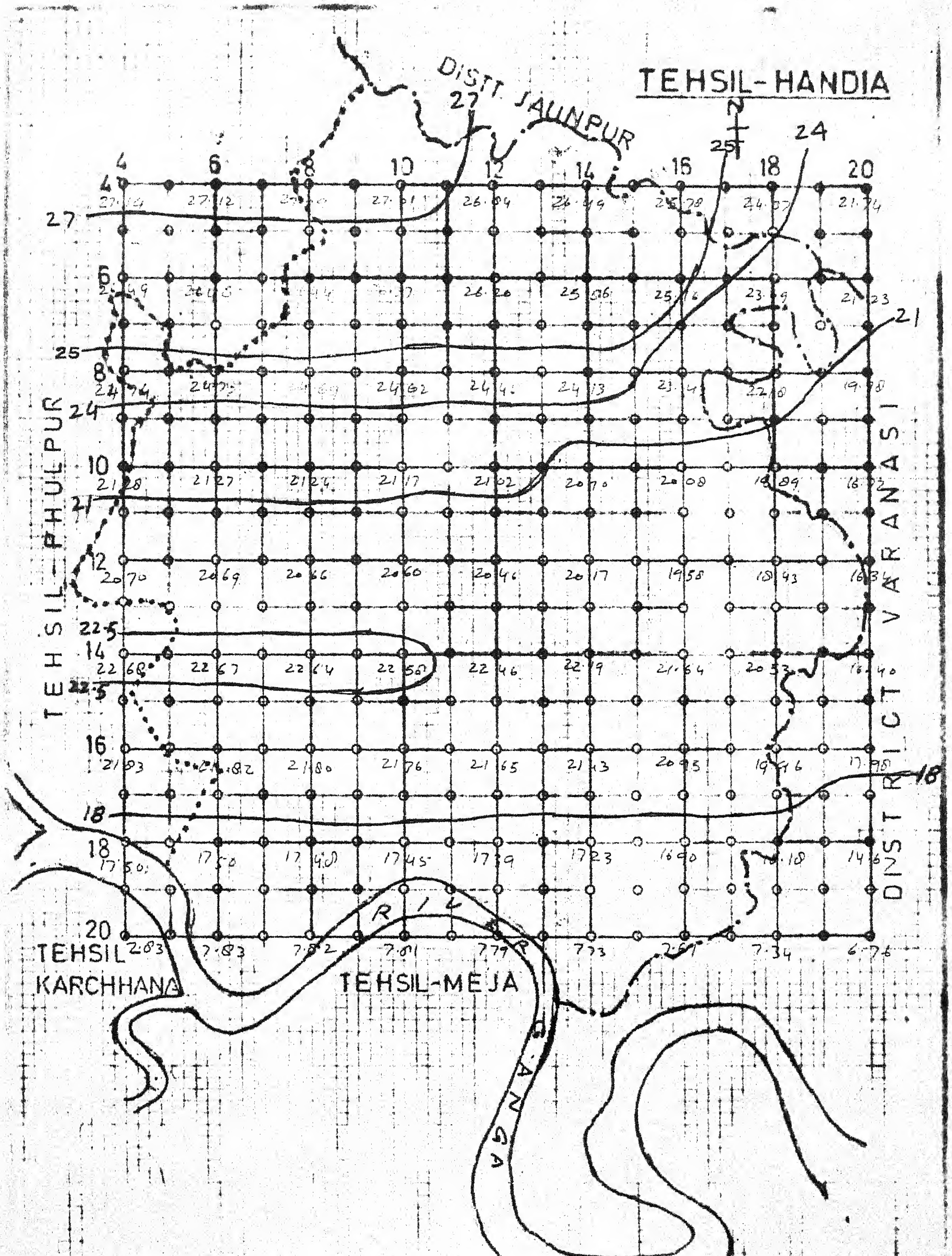


FIG. 30 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT.)
RUN No. 7

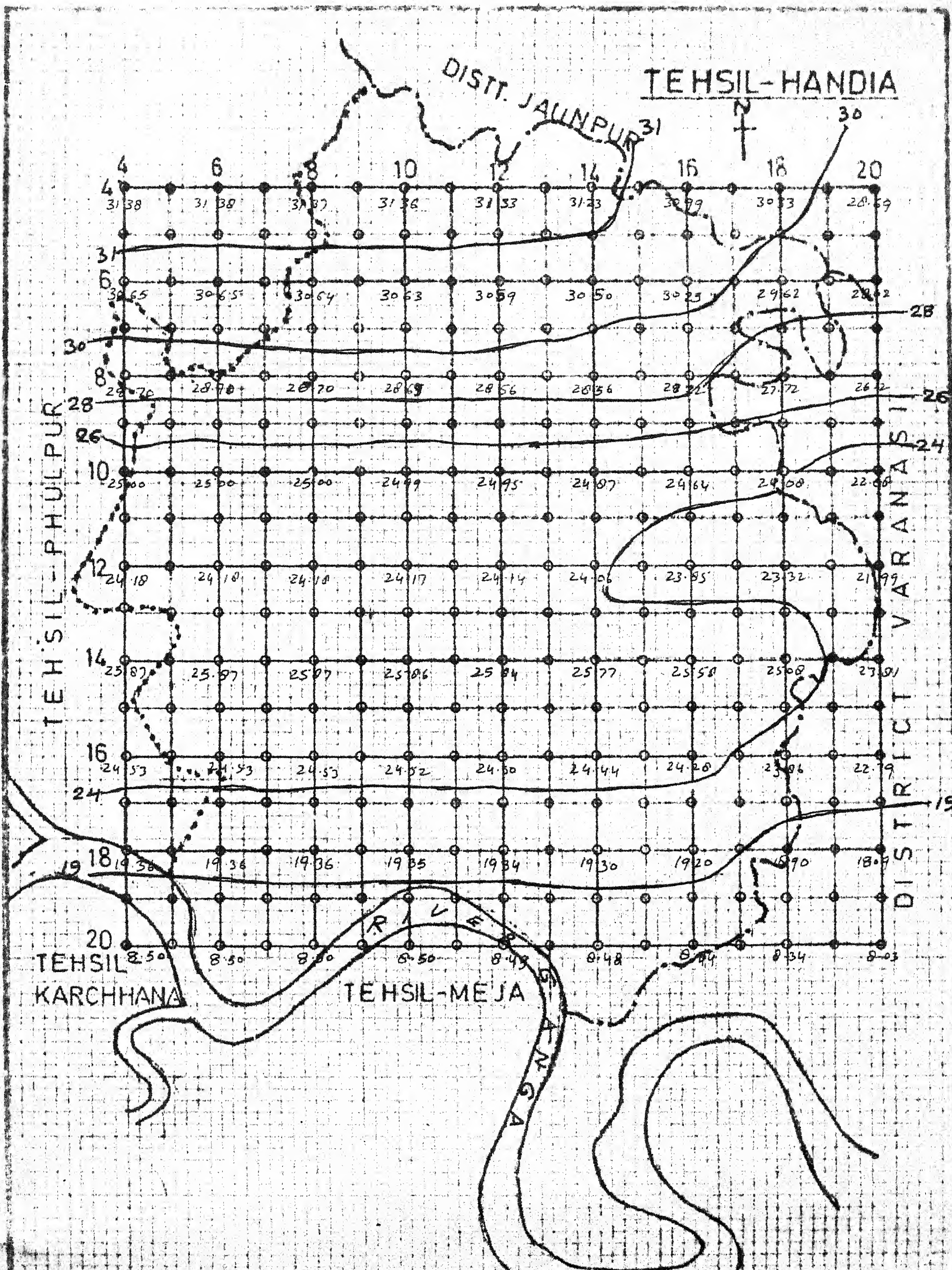


FIG. 31 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT)
RUN No. 8

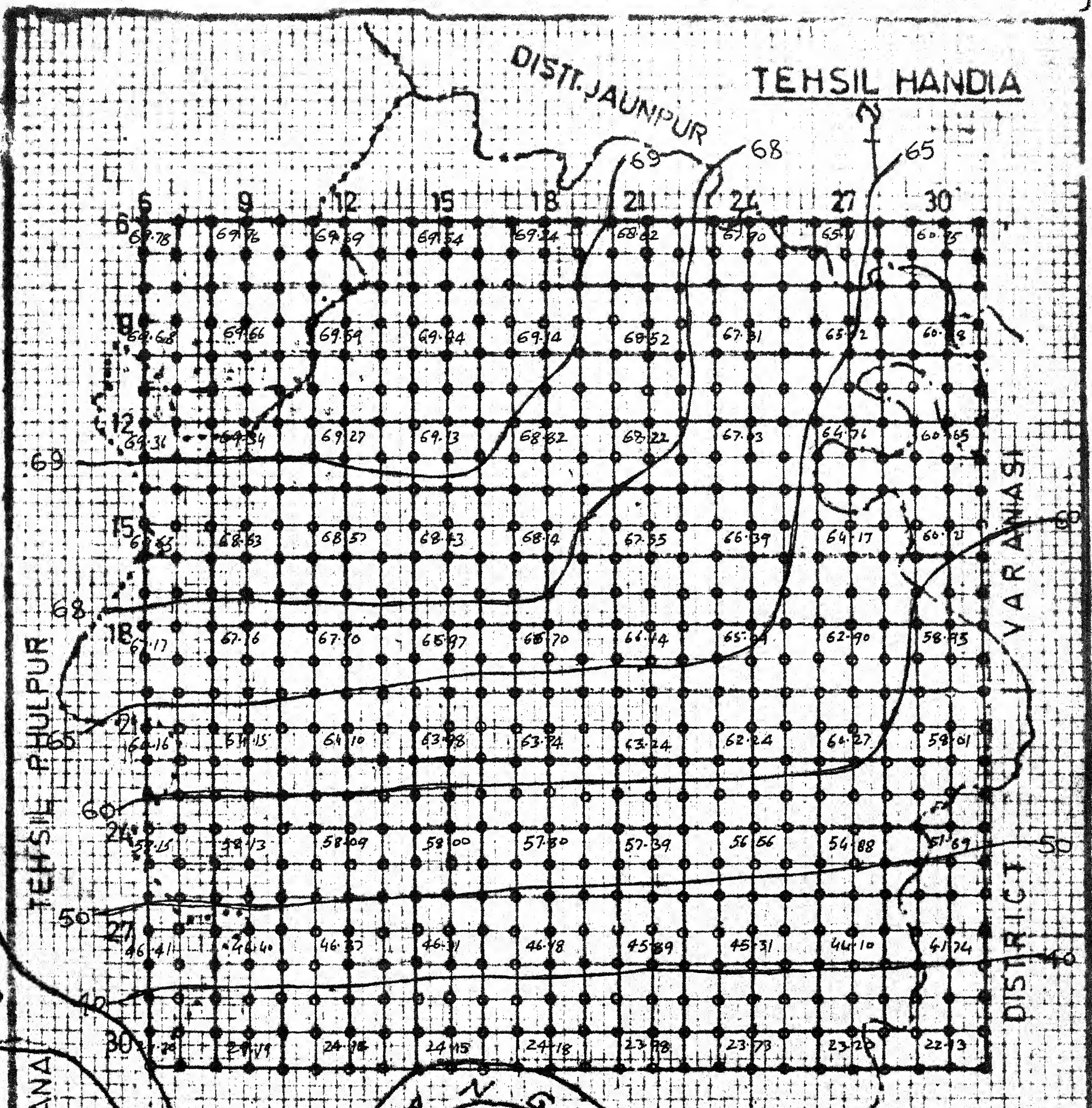


FIG 32 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES(IN FT)
RUN No. 9

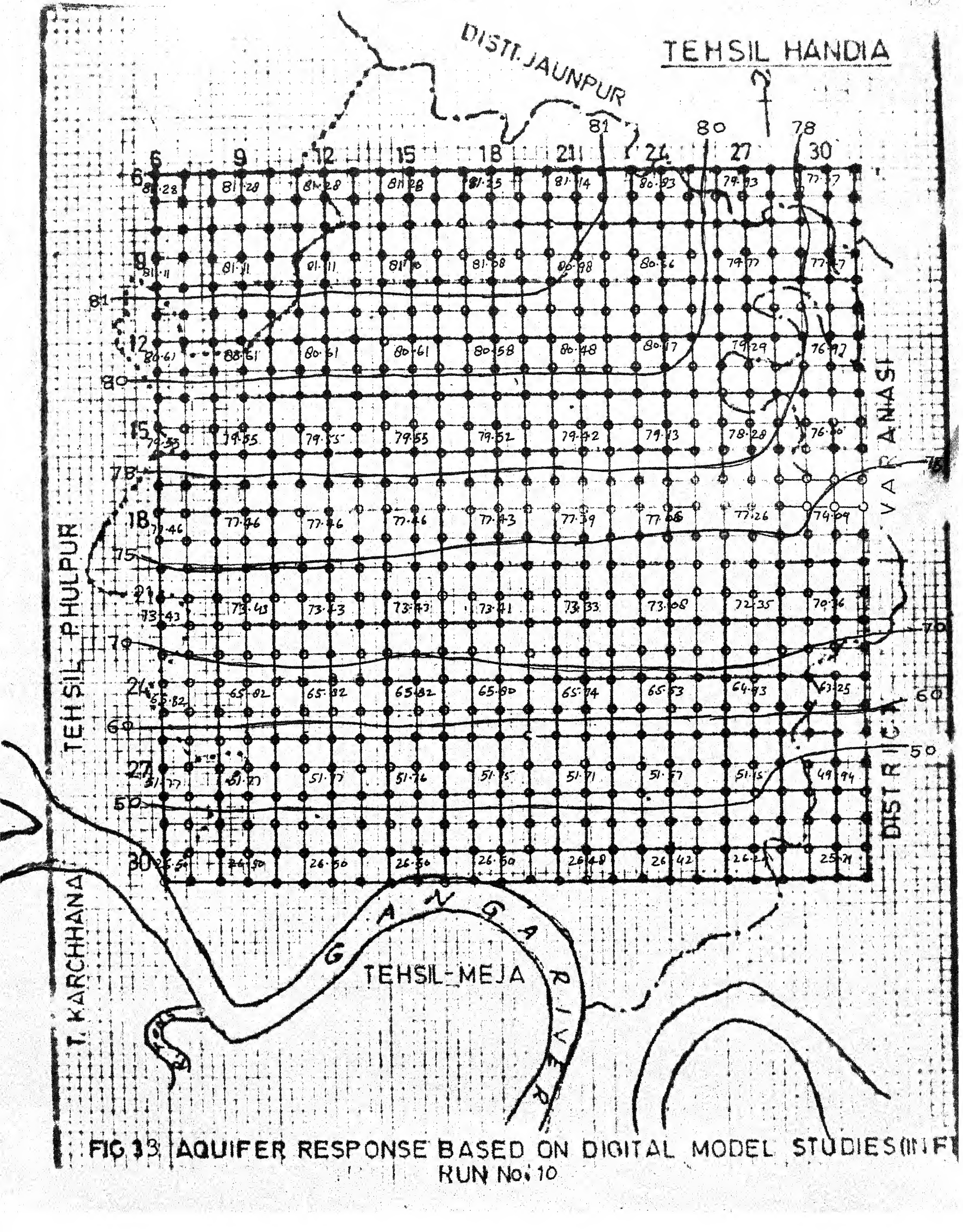


FIG 33 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES(INF
RUN No. 10

The second policy of recharge-discharge operation tried is the following. It is assumed that a large quantity of surplus water during monsoon period will be available. Hence 102 recharging tube-wells are assumed to be distributed more and less uniformly in the middle of the area. These 102 (17 x 6) recharge tube-wells are assumed to operate during the Kharif period of roughly 100 days. During this period 187 pumping wells are also assumed to be working simultaneously. At the end of the Kharif period recharging is stopped and all the recharging wells are converted into pumping wells. Hence in the Rabi period all the 289 tube-wells will be pumping from the aquifer.

The effect of this type of recharge-discharge policy can be seen from Fig. 34. This figure is compared with Fig. 26 and it is seen that the effect of using surplus surface water for recharging during Kharif season is to reduce drawdown in the aquifer and the amount of reduction in this case is about 1.8 m (6 ft.) over a large part of the area under study.

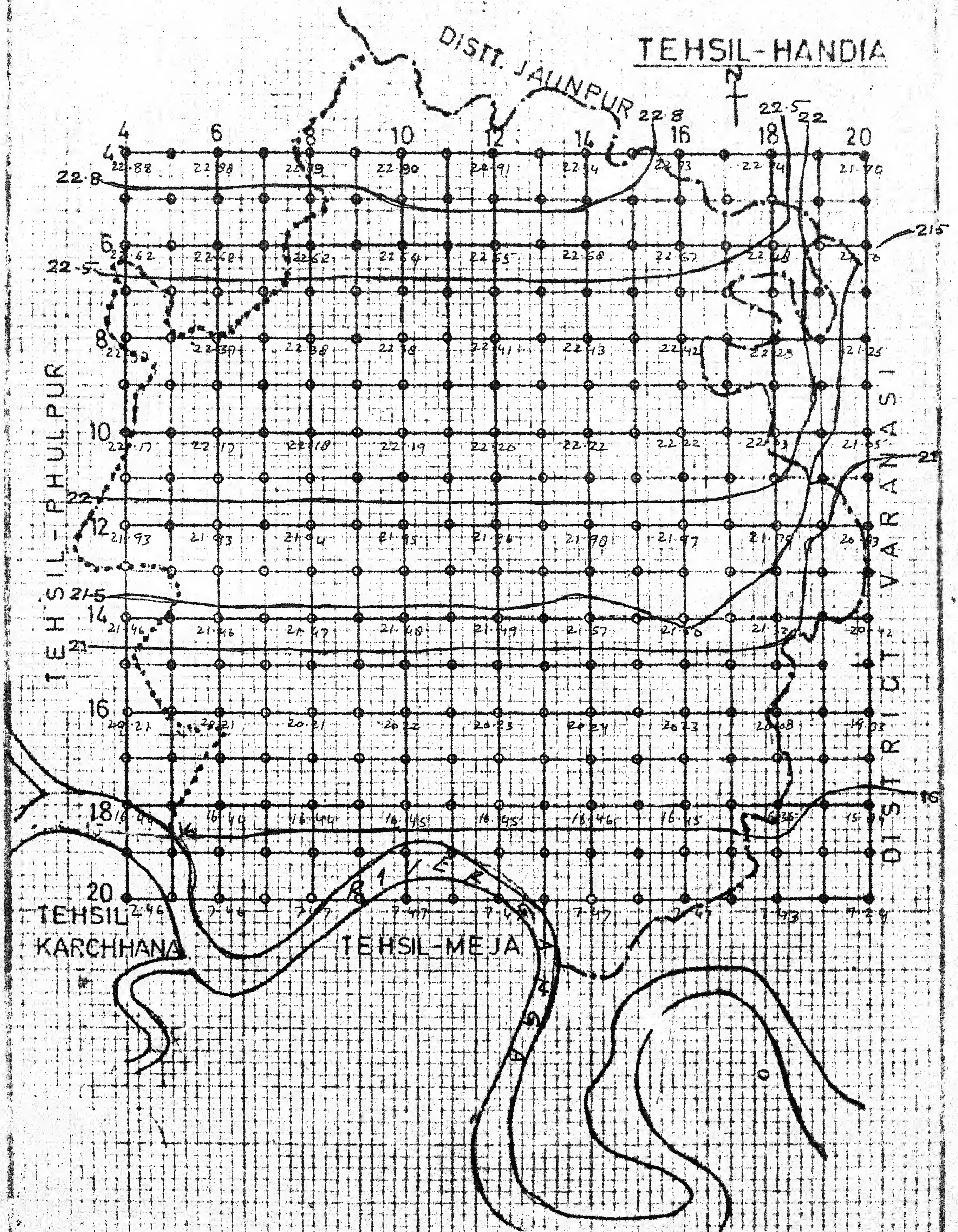


FIG 34 AQUIFER RESPONSE BASED ON DIGITAL MODEL STUDIES (IN FT.)
RUN No. 11

5.8 GENERAL REMARK AND CONCLUSION:

In the analysis done so far, we treated only the state-tube-wells pumping from the lower aquifer. There are quite a number of Minor Irrigation Works (MW, PTW and PPS) pumping from depth 30 m (100 feet) to 60 m (200 feet). Because of the leaky nature of the aquifer, the upper aquifer is going to be affected by pumping of the lower aquifer and vise-versa. This kind of interaction has been not taken into account in the present analysis. It is possible to take this interaction into account if suitable pumping tests are conducted in the basin and the results obtained. Further it is also assumed in the present analysis that the discharge from the lower aquifer is balanced by recharge due to leakage and recharge from river Ganga.

By a scheme of recharging it is possible to manage the aquifer in the Handia Tehsil such that the piezometric surface does not go below pumping bowl levels. The actual type of recharging facilities have not been considered in the report. It is only assumed on the basis of personal experience(see annexture 4) author during his posting in tube-well sub-division I, Handia, that enough surplus surface water is available in the monsoon period, which flows to river Ganga. This surplus water accumulates in several big ponds or 'Tals' or pass away through drains, which can be utilised to recharge the ground water

basin of the area at reasonable costs.

It is understood thatthere is a scheme to bring in canal water into this area under the Sharda Sahayak scheme, If this is so then the canal water should be used in conjunction with the ground water in the area. The conjunctive utilisation can be in the form of supply of canal water during part of Kharif and Rabi season and remaining water to be supplied by ground water such that at least 200% irrigation intensity is realised over the entire basin. (It is likely that the canal water might have been designed to achieve about 150% irrigation efficiency.)

Since there is already a large capital outlay on the tube-wells in the basin, it seems to be economical to use this capital outlay as fully as possible by a proper recharge-discharge operating policy such that the piezometric surface does not fall below the pump bowl level and divert surplus canal water to areas where ground water is not available in sufficient quantity.

5.9 SUGGESTED IMPROVEMENTS IN THE MODEL:

1. The geometry assumed for the model in the present studies is rather simple. It is a square geometry, bounded on the south by Ganga river assumed to be a line recharge source. From a look at the Fig. 26 it can be seen that

this square geometry can be improved. A stepped line can be used to follow the river boundary much more closely.

2. The other three boundaries are assumed to be impervious boundaries on the assumption that the tube-wells out side the boundaries are so far away that there effect are not felt in the area under consideration. Improvement in this also can be made if we know exactly how the euter tube-wells are located and their operating conditions.

3. It is assumed in the present analysis that the aquifer has uniform properties such as coefficient of storage and transmissibility. In relating this may not be true. However variations in the aquifer parameters over the region can easily be incorporated in the digital model. This would require a proper hydrogeological survey of the area to determine variations in the aquifer characteristics and also a proper monitoring of the changes in the piezometric surface over a few years at suitable intervals of time.

4. As already mentioned before the interection between the different aquifers is not taken into account in the present study. This can be included in a digital model if sufficient data are available for different aquifers.

5. To determine the type of artificial recharge facility best suited, it is necessary to make a cost analysis.

6. A water balance for the area also requires to be done to determine more accurately the natural recharge. This can be done by a watershed simulation analysis for the area if all the data are made available.

REFERENCES

1. Agriculture Directorate, U.P. (1975), "Agricultural Statistics of U.P."

2. Bhattacharya, A.P.,(1954), "Behaviour of the Sub-soil Water-table in tracts of Western U.P.(India) as affected by a System of Tube-well Irrigation". International Commission on Irrigation and Drainage, Algiers.

3. Boulton, N.S.(1954), "Unsteady radial flow to a pumped well allowing for delayed yeild from storage", Internat. Assoc. Sci. Hydrology Pub. 37, p. 472-477.

4. Boulton, N.S. (1954), "The drawdown of the water table under nonsteady conditions near a pumped well in an unconfined formation", Inst. Civil Engineers Proc.(British), pt.3, p. 564-579.

5. Boulton, N.S. (1963), "Analysis of data from non-equilibrium pumping tests allowing for delayed yield from storage", Inst. Civil Engineer Proc. (British), v.26, p. 469-482.

6. Boulton, N.S. (1964), Discussion of "Analysis of data from non equilibrium pumping tests allowing for delayed yield from storage" by N. S. Boulton., Inst. Civil Engineer Proc. (British), v.28, p.603-610,(Discussions by R.W. Stallman, W.C. Walton, and J. , Ineson and reply by author).

7. Bhatanagar, N. (1965), "Progress Report of Systematic Geohydrological Studies in Part of Allahabad and Mirzapur Districts(Field Season 1964-65) G.S.I. (non-secrete).

8. Biswas, A.K. (1976), "System Approach to Water Management", McGraw Hill Book Company, New York.

9. Bahadur, P., Asthana, M.C., Bisaria, B.K., Malviya, A.K., Sharma, V. (1974), "Report on the Technical, Feasibility of Ground Water Development in District Allahabad",,T.M. No. 5, F.R. (L-9),G.W.I.O.I.D., Lucknow,(unpublished).

10. Bahadur, P., Saksena, R.S. (1976), "Preliminary report on Geohydrological Investigation to design well field in Phulpur, Distt. Allahabad," T.M. No.7,(GWD-7), G.W.I.O.,I.D. Lucknow (unpublished).

11. Bahadur, P., and Saksena, R.S. (1975), "Ground Water Potential in U.P. an Appraisal", Proc. of National Symposium on Hydrology, University of Roorkee, Roorkee.

12. Bahadur, P. and Saksena, R.S. (1976), "Ground Water Status in Ramganga Command Area," Ground Water Directorate, Lucknow, India.

13. Bisaria, B.K. and Roy, R.K. (1976), "Quaternary Sediments and Ground Water Resources of Mainpuri District, Uttar Pradesh",Proc. Symp. on the Contribution of Earth Sciences Towards Research and Developmental Activities in the N.Region, Lucknow, Vol.I., Sec.1, Paper I.A. 2.

14. By Communication-Irrigation Department, U.P., data of S.T.Ws'.

15. By Communication-Minor Irrigation Department, U.P., data for Minor Irrigation-Works.

16. By Communication-Central Ground Water Board, Lucknow, data for the study area.

17. By Communication- India Meteorological Department, Lucknow, data for Climatology, Rainfall, etc.

18. By Communication- Geological Survey of India, Lucknow, data regarding the study area.

19. By Communication- Chandra Shekhar Azad Agricultural and Technological University, Kanpur, data regarding rainfall and Pan Evaporation and other Climatological details.

20. By Communication- Ground Water Investigation Organization Lucknow, data regarding water table and other details.

21. Bennet, G.D., Etal- , "Analysis of Aquifer Tests in the Punjab Region of West Pakistan"- U.S.G.S. Water Supply Paper 1608-G.

22. Chaterjee, G.C. (1969), "The Status of Geohydrology in India"- Water Resources Bulletin, Vol. 5-3, 3-18.

23. Chaturvedi, R.S. and Pathak, P.N. (1963), "Flow of Ground Water Towards Pumping Wells in the Viscinity of a Perennial Stream", Univ. of Roorkee Research, Journal, Vol. VI, No.II, pp. 97-122.

24. Chaturvedi, R.S. and Pathak, P.N. (1965), "The Flow of Ground Water Towards Pumping Wells and the Optimum Yield Under Varying Geo-Hydrological Conditions", CBIP, Publication No. 69.

25. Chaturvedi, P.C., (1977), "Hydrogeological Investigations in the Mirzapur Area, U.P.", Unpublished M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology, Kanpur.

26. Chow, V.T. (1952), "On the Determination of Transmissibili and Storage Coefficients from Pumping Test Data", Am. Geophys. Union Trans. V. 33, No.3, pp. 397-404.

27. Chawdhury, B.K. (1971), "Economics of Tube-well Irrigatior in West-Bengal", Agro-Economic Research Centre, Visva-Bhai Santiniketan.

28. Critchfield, H.J. (1966), "General Climatology" ,Prentice-Hall Inc. Englewood Cliffs, New Jersey.

29. Dewiest, R.J.M. (1966), "Hydraulics Model Study of Nonsteady Flow to Multi-aquifer Wells", Journal of Geophysical Research Vol.71, No.4.

30. Dubey, M.C. 1969), "A note on Geohydrological Investigation in Parts of Dehradun and Saharanpur Distric of Uttar Pradesh and Ambala District of Haryana"-Proc. Symp. on Ground Water, G.S.I., Calcutta, Miscellaneous Publication No. 14, 230-237.

31. Ferris, J.G., Knowles, D.B., Brown, R.H. and Stallman, R.W., "Theory of Aquifer Tests", U.S.G.S. Water Supply paper 1536-E, 1962.

32. Gokhale, K.V.G.K. (1971), "A Case Study for Hydrogeological Investigations in Planning for Ground Water Exploitation", Seventh Symposium, The Civil and Hydraulic Engineering Department, Water Resources, I.I.S.C. Bangalore, pp. B-11-1 to B-11-5.

33. Gupta, B.L. (1968), "Hydrogeological Studies in Muzzaffarnagar and Parts of Meerut Districts, U.P.(India), Ph.D. thesis (unpublished), University of Roorkee, Roorkee.

34. Hantush, M.S. and Jacob, C.E. (1955), "Nonsteady Radial Flow in an Infinite Leaky Aquifer", Am. Geophys. Union Trans., V. 36, No.1, p. 95-100.

35. Hantush, M.S. (1956), "Nonsteady Flow to Flowing Wells in Leaky Aquifer", Journal of Geophysical Research, Vol.64, pp. 1043-1052.

36. Hantush, M.S., (1960), "Modification of the Theory of Leaky Aquifers", Jour., Geophys. Research, V. 65, no.11, p. 3713-3725.

37. Hantush, M.S. (1964), "Drawdown Around Wells of Variable Discharge", Journal of Geophysical Research, Vol.69, No. 20, pp. 4221-4285.

38. Hasan, N., Malviya, A.K., and Choudhari, N.K. (1974), "Analysis of Pump Test Data Collected From State Tubewell No. 26 Bhadohi Group, In District Varanasi, U.P., T.M. No. 5 P.R. (L-10), G.W.I.O. I.D., U.P., Lucknow(unpublished

39. Hasan, N., Malviya, A.K., Bisaria, B.K. (1974), "Analysis of Pump Test Data Collected from Raghopur State Tube-well of Bhadohi Group in District Varnasi, (U.P.), T.M.No.5 P.R. (L-12), G.W.I.O., I.D., U.P. Lucknow.

40. Irrigation Research Institute Roorkee, (1961), "Qualititativ Analysis of the Effect of Tube-well Pumping on Ground Water Table in Doabs east of the Ganga River of U.P.", T.M. No. 31, R.R. (Hy.42),

41. Irrigation Research Institute Roorkee, (1968), "Behaviour of Groundwater Table in Ganga - Ghagra Doab of U.P." T.M. No. 39- R.R. (G.2).

42. Irrigation Research Institute Roorkee, (1969), "Behaviour of Groundwater Table in Ganga-Sarda Doab of U.P.- T.M. No. 39- R.R. (G-27).

43. Indian Council of Agricultural Research (I.C.A.R.), New Delhi (1968), "Proceedings of the Symposium on Cropping Patterns in India (Held at Delhi on Jan. 27-31).

44. Joglekar, D.V., (1965), "Irrigation Research in India", Central Board of Irrigation and Power, Pub. No. 78.

45. Jones, P.H. and Hofmann, W. (1967), "Water Resources Investigation Programme for Upper Gangetic Plain"-India, U.S. Department of Interior (Geological Survey) Report.

46. Kumar, H., Singh, R , Malviya, A.K. and Bisaria, B.K. (1974), "Report on the Technical Feasibility of Ground Water Development on Compact Area Basis at Phulpur, Baheria, Bahadurpur and Pratappur Blocks of District Allahabad", G.W.I.O., I.D., U.P. (unpublished).T.M. No.4 R.R.(2-8).

47. Khanna, S.P. (1973), "Ground Water in Mirzapur District Uttar Pradesh"- Report, Central Ground Water Board, Lucknow.

48. Khanna, S.P. (1974), "Ground Water Conditions in Allahabad District, Uttar Pradesh"-Report, Central Ground Water Board, Lucknow.

49. Lakshminarayana, V. (1970), "Computers in the Management of Ground Water Resources", Proceedings Fortieth Annual Research Session, Shillong, Assam, C.B.I.P. , Pub.No. 104, V. 1-C (Hydraulics).

50. Lakshminarayana, V. , Subramanian, R., and P.K. Kognolkar (1975), "Direct Electric Analog Simulation of An Unconfined Aquifer", Proceedings of National Symposium on Hydrology, University of Roorkee, Roorkee.

51. Mehta,D. and Adyalkar, P.G. (1962), "Tarai and Bhabar Zones of India Along the Himalayan Foot Hills as Potential Ground Water Reservoirs"- Economic Geology, Vol. 57, 367-376.

52. Mehta, D.,(1960), "Ground Water Exploration in India", United Nations ECAFE Colombo Conference on Water Resources Development.

53. Moore, J.E., and Leonard, A.W. (1967), "Ground Water", Vol. 15, No.1, pp. 20-23.

54. Mithal, R.S. (1969), "A Reappraisal of Ground Water Distribution and Provinces in India", Proc. Symp. on Ground Water Studies in Arid and Semi-arid regions, Roorkee, pp. 495-526.

55. Mithal, R.S., Singhal, B.B.S. and Bajpai, I.P. (1973), "Ground Water Conditions in the Gangetic Alluvium of Western Uttar Pradesh", International Symposium on Development of Ground Water Resources, Proc. Vol.3, Madras, pp. V-53-V-61.

56. Mehrotra, C.L. (1968), "Soil Survey of Allahabad District" Survey and Soil Work in U.P., Vol.V, Deptt. of Agriculture

57. Narasimhan, T.N. (1968), "Ratio Method for Determining Characteristics of Ideal, Leaky and Bounded Aquifers", Bull. Assoc. Sci. Hydrol. No.1.

58. Nautiyal, S.P. (1955), "Artesian Water Supply of Tarai and Bhabar Zones of U.P.", Central Board of Geophysical Publ. No.4, pp. 49-66.

59. Pathak, B.D. (1954), "Preliminary Report on Ground Water Conditions and the Selection of Sites for Exploratory Bore Holes in U.P.", Geological Survey of India Memo No.

60. Pathak, B.D. (1955), "The Occurrance of Ground Water in the Alluvial Tracts of U.P. (India)", Central Board of Geoph. Publication No.4, pp- 42.48.

61. Pathak, B.D. (1969), "Geology and Ground Water Condition in the Basti, Gorakhpur and Deoria Districts of Uttar Pradesh", Proc. Symp. on Ground Water Studies in Arid and Semi-arid Regions, Roorkee, 55-76.

62. Pathak, B.D. , Venktesan, S. and Bhattacharya, S.C.(1976 "Recent Findings of Ground Water Exploration in Uttar Pradesh" Proc. Symp. on the Contribution of the Earth Sciences Towards the Research and Developmental Activiti in the N.Region, Vol.I, IA.1.

63. Pandey, M.P., Raghava Rao, K.V. and Karnath, K.R.(1961), "Evaluation of Ground Water Potentialities of the Bhabar Formations of U.P.", Ind. Sci. Cong. 48th Session, pp. 212-213.

64. Prickett, T.A. and Lonnquist, C.G. (1968), IASH, Symposium of Tuscon, Arizona.

65. Prickett, T.A. (1975), "Modelling Technique for Ground Water Evaluation", Advance in Hydro Science, edited by Chow, V., Vol.10.

66. Patel, S.M. and Patel, K.V. (1971), "Economics of Tube-well Irrigation", Indian Institute of Management, Ahmedabad.

67. Prasad, N.K. (1973), "Short Term Evaporation Studies of Some Observed Pan Data", (unpublished).

68. Prickett, T.A. (1967), "Designing Pumped Well Characteristics into Electric Analog Model", G.W.5, 54, 38 46.

69. Radhakrishna , B.P.- ,"Technical Evaluation of Minor Irrigation Schemes in Lakhimpur-Kheri and Bijnor districts of U.P.".

70. Raghava Rao, K. (1965), "Hydrogeological Studies of Alluvial Areas in Parts of Sharanpur District", Ph.D. Thesis (unpublished), University of Roorkee, Roorkee.

71. Radhakrishnan, R., (1969),"Simulation Technique-Yield of Aquifer Design of Continuous Resistance Analogue Computer", Symposium on Simulation Techniques and Prototype Behaviour in Water Resources System, C.B.I.P. New Delhi.

72. Ramaseshan, S. (1976), "Lecture Notes , Vol.I and II, Advanced Summer School on Systems Analysis of Hydrologic Problems, May 5 to July 10, IIT Kanpur.

73. Remson, I., Appel, C.A. and Webster, R.A.,(1965), "Ground Water Models Solved by Digital Computers", Jnl. Hyd. Div., A.S.C.E., H.Y.3, 1965.

74. Rushton, K.R., and Bannister, R.G. (1970), "Ground Water", Vol.8, No.4.

75. Stampe, Sir William(1934-1938), "The Ganges Valley State Tube-well Irrigation Scheme-A System of State Irrigation by Hydro-Electric Power from Underground Sources".

76. Singh, S.P., Kumar H., et.al. (1973), Notes on Geological Formation in Uttar Pradesh , T.M. No.3, L-7, GW 10, U.P.

77. Singhal, B.B.S. (1963), "Some Problems in the Application of Common Pumping Test Methods to Field Conditions", Journal of the Institution of Engineers India (Civil Engineering Division), Vol.44, 443-457.

78. Singhal, B.B.S. and Gupta, B.L. (1966), "Analysis of Pumping Test Data from a Well in the Indo-Gangetic Alluvium of India and its Bearing on the Aquifer Characteristics", Journal of Hydrology, Vol.4, pp. 121-140.

79. Saksena, R.S. (1974), "Water Balance Study of Ganga-Ramganga Doab" A Dissertation for the Degree of Master of Engineering in Hydrology,(unpublished),University of

80. Taylor, E Mckenzie, (1936), "Report on the Possible Lowering of the Water-table in United Provinces as a Result of Tube-well Pumping", Superintendent, Printing and Stationery, United Provinces, Allahabad.

81. Taylor (Jr.), G.C. (1959), "Ground Water Provinces of India", Economic Geology, Vol.54, 683-697.

82. Theis, C.V., (1935), "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-water Storage", Am.Geophys, Union Trans., v. 16, p. 519, 524.

83. Tyson, H.N. and E.H. Weber, (1964), J. Hyd. Div, ASCE, Vol. 90, No.4.

84. Venkatachaliah, (1974), "A Study of Ground Water Potential at I.I.T. Campus, Kanpur", Unpublished M.Tech. Thesis, Department of Civil Engineering, I.I.T. Kanpur.

85. Walton, W.C. and Neill, J.C., (1960), "Analyzing Ground Water Problems with Mathematical Models and a Digital Computer", Int. Assoc. Sci. Hydro., Pub. No.52, Helsinki.

86. Walton, W.C. (1962), "Selected Analytical Methods for Well and Aquifer Evaluation", Illinois State Water Survey, Bulletin 49.

87. Walton, W.C., and Prickett, T.A. (1963), J. Hyd. Div., ASCE, Vol. 89, Hy. 6.

Walton, W.C., (1970), Ground Water Resource Evaluation, McGraw-Hill, New York.

White, N.D., and Handt, (1965), U.S.G.S., Water paper 1809-R.

ANNEXTURE 1

HISTORY CHART OF WORKING OF SOME STATE TUBE-WELLS OF HANDIA TEHSIL

* Cell No. 3 .... STW-24 H Village Ausanpur

Fasali Year	Discharge				Area Irrigated in Acres				Hours Runs			Irrigation wate supplied per Bigha(in gallons	
	Kharif		Rabi		Sugar-cane	Other Kharif	Total Crop Area in Acres	Rabi	Kha-rif	Rabi	Total	Rabi	Kharif
	Disch. GPH	Depre. FT	Disch. GPH	Depre Ft.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1369	33200	12	33200	12	3	32	179	214	194	566	760	57668	81183
1370	33200	12	37700	12	21	99	281	407	1046	1259	2305	63276	82654
1371	37700	12	37700	12	30	108	403	531	1298	2249	3547	83346	105688
1372	37700	14	35400	12	22	94	435	551	1524	3678	5202	85703	124139
1373	35400	17	27204	12	46	158	421	625	3111	3102	6213	71690	113140
1374	27200	16	27000	14	33	167	386	586	2278	1759	4037	52091	101267
1375	31000	14	31000	13	7	117	396	520	1884	3453	5337	105339	835454
1376	28372	14	24600	14	11	161	265	437	3086	3743	6829	93687	149412
1377	24200	14	24200	14	11	71	254	336	1744	2583	4327	81748	162953
1378	24200	14	24200	14	8	64	177	249	1528	2704	4231	85512	168801
1379	24200	14	24200	14	1	51	191	293	882	3438	3320	87119	133254
1380	24200	14	24200	14	2	64	133	199	1320	1680	3000	98148	138891
1381	24200	14	24000	14	3	32	120	155	815	1298	2113	63176	143055

* The whole area is devided into 30 cells. History charts of some of the STWS' are given in this Annexture 1.

nnexture 1 contd.. . Cell No. 8 contd.... BTW-24H Village Ausanpur contd....

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1382	15000	13	24000	13	3	41	157	201	782	1724	2605	76575	66648
1383	24000	13	24000	13	3	59	205	267	1421	2740	4161	78200	114403
1384	-	-	-	-	-	52	119	171	754	1772	2826	-	-
Cell No. 8 contd.... STW-79 H Village Rasar													
1365	35400	20	35400	20	7	6	131	144	90	555	645	72770	106200
1366	35400	20	35400	20	12	26	79	117	405	287	692	78187	91318
1367	35400	20	35400	21	15	58	115	188	494	531	1025	77355	87877
1368	35400	20	35400	20	13	31	99	143	532	452	984	73131	77581
1369	35400	20	35400	22	10	44	71	125	618	257	875	70193	109386
1370	35400	20	35400	22	13	36	95	144	663	397	1060	72449	10845
1371	35400	22	35400	20	21	31	229	231	566	1417	1923	87942	104136
1372	35400	20	33234	20	22	69	296	387	1057	2128	3185	88802	39167
1373	35400	20	31210	20	37	148	351	526	2743	2526	5274	51181	149640
1374	27100	17	27100	19	21	194	401	616	2365	2533	4898	61371	99650
1375	27340	19	28371	16	19	97	344	460	1616	2077	3693	61279	91489
1376	24600	15	21600	15	38	191	356	585	2976	4074	7050	178354	92772
1377	24200	15	24200	15	32	82	291	405	2031	2223	4254	78118	114393
1378	-	-	-	-	-	-	-	-	-	-	-	-	-
1379	29200	15	26200	15	4	53	217	274	710	1936	2646	63866	116310
1380	26200	15	24200	15	5	72	186	263	1501	1504	3005	80329	119500

Annexture 1 contd..Cell No. 8 contd.... STW-79 H Village Rasar

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1381	24200	20	24000	15	10	41	130	181	823	1429	2252	70665	111655
1382	24200	15	24200	18	5	40	146	192	608	1645	2251	174733	113025
1383	24200	15	24200	15	13	82	215	310	1378	2670	4048	89246	134041
1384	-	-	-	-	-	70	112	182	1404	2076	3490	89246	-

Cell No. 8 contd.... STW-81H Village Deutha

1365	36200	20	36200	20	9	15	214	238	124	900	1024	45521	77393
1366	36200	20	36500	20	14	29	160	203	381	518	899	68206	87292
1367	36500	11	36500	11	12	72	214	298	523	876	1399	74881	85776
1368	36500	11	36500	11	13	37	204	254	559	763	1322	79012	47783
1369	36500	11	36500	12	22	41	192	255	564	634	1188	67858	91550
1370	36500	11	40000	12	19	32	218	269	456	973	1429	46247	95109
1371	40000	12	40000	12	23	32	315	370	449	1764	2213	90431	112114
1372	40000	14	40000	12	12	72	296	380	967	1433	2450	176054	115123
1373	40000	14	31000	12	30	157	638	625	1834	2487	4321	77076	124370
1374	35500	16	31000	19	22	200	738	760	2194	2818	5012	-	188446
1375	35000	18	34400	17	30	92	475	597	1770	2873	4643	83128	109975
1376	24600	12	33400	13	33	177	387	597	3047	4293	7340	90717	123255
1377	31800	14	33780	14	54	57	282	393	1883	2030	3913	155222	132344

Annexture 1 contd..Cell No. 8 contd.... STW-81 H Village Deutha Contd.....

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1378	32940	14	32825	14	30	36	247	313	1088	2457	3545	90972	170038
1379	32825	14	31800	14	10	42	292	344	591	2396	2987	81793	147093
1380	31800	14	31800	14	10	95	193	303	2033	1667	3700	75825	123032
1381	31800	14	30000	16	22	26	156	204	1001	1470	2471	163779	168513
1382	31800	14	31800	16	16	32	171	219	723	1683	2406	98744	143710
1383	31800	16	29350	13	12	39	205	256	886	2678	3564	107746	17386
1384	-	-	-	-	-	62	159	221	1303	2258	3561	-	-
		Cell No. 15 STW - 149 H Village Raniadih											
1376	36313	12	36800	12	2	87	330	419	760	2900	3660	102354	106380
1377	36200	12	32820	14	11	110	231	352	1535	1568	3103	916314	150146
1378	30300	13	36720	11	10	81	274	365	612	2530	3142	89654	85871
1379	32000	12	32000	12	5	72	269	347	652	2035	2687	87619	122698
1380	32000	12	32000	12	4	95	204	303	1607	1770	3377	115810	142090
1381	35400	12	35400	12	2	31	104	137	694	1208	1902	70800	220015
1382	28000	12	27000	12	2	53	136	191	583	1483	1066	94857	106612
1383	28200	12	26000	12	2	65	147	214	908	2444	3352	107747	132672
1384	-	-	-	-	-	49	88	137	909	1346	2255	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1365	26200	20	26900	20	2	10	184	196	39	813	852	71098	70590
1366	26200	20	37700	20	45	28	193	196	646	384	1030	66104	92482
1367	37700	20	37700	20	38	102	204	344	780	869	1649	79903	84017
1368	37700	20	37700	20	42	36	176	254	671	683	1354	76148	56615
1369	37700	20	37700	20	47	30	126	204	741	442	1183	81874	125815
1370	37700	20	37700	20	41	50	198	295	847	801	1648	99316	123232
1371	37720	20	377 0	20	50	32	274	359	895	1233	2128	77234	133378
1372	33500	17	23500	20	61	83	331	475	1810	2337	4147	76020	289561
1373	23500	17	20300	20	100	157	458	715	3140	3550	6690	58660	109293
1374	23500	20	28020	20	90	109	410	659	2999	2881	5880	82260	83099
1375	28020	20	28000	16	55	96	281	430	1916	1586	3502	73432	88821
1376	32420	14	32400	16	63	171	419	659	3321	4268	7589	72382	125814
1377	30900	16	31800 36200	16 20	72	106	311	489	1931	2071	4002	100416	136547
1378	26200	20	31790	20	22	73	277	372	1149	1810	2959	86032	176283
1379	36813	20	31800	16	12	56	268	336	898	1961	2859	89158	201520
1380	36200	16	26200	16	37	71	203	311	1332	1603	2935	139001	155018
1381	36210	16	36000	17	31	22	206	259	808	1292	2100	81469	187219
1382	36000	15	31814	16	20	53	206	279	627	1500	2127	113852	126067
1383	31814	16	24000	16	16	106	227	349	932	2562	3494	128132	121420
1384	–	–	–	–	–	9	108	117	179	1901	2080	–	–

Annexture 1 contd. Cell No. 12 contd.... STW 33 H Village Shahipur

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1365	-	-	26200	-	-	-	10	10	-	27	27	63882	-
1366	26200	-	26200	-	18	18	99	135	233	283	516	58308	75464
1367	33200	17	33200	10	34	95	237	366	711	926	1637	67568	78163
1368	33200	17	33200	17	59	45	274	378	937	912	1849	61859	68370
1369	33200	17	33200	17	81	55	222	358	1274	730	1944	61781	88799
1370	33200	16	33200	17	70	51	276	397	1101	933	2034	66542	100421
1371	33200	16	33200	12	71	44	384	499	1026	1580	2606	41721	948413
1372	33200	14	33200	12	69	62	334	465	1155	1723	2878	82190	99586
1373	33200	12	31100	18	86	164	507	757	2661	3210	5871	87494	115653
1374	31100	18	31181	19	76	173	553	802	2532	2749	5281	78954	136386
1375	33230	18	36813	11	27	118	373	518	1847	2104	2951	94147	140579
1376	35498	15	35600	15	25	200	452	677	2479	3773	6252	106794	187110
1377	35600	15	33780	10	53	75	279	407	1774	2113	3887	120978	197257
1378	32500	11	36450	12	21	117	207	272	1123	1636	2759	108178	175083
1379	34580	13	31625	16	24	64	217	302	958	2023	2981	107292	183840
1380	31625	15	32200	15	28	115	142	235	1667	1075	2749	140569	183840
1381	31625	15	27840	15	12	84	108	144	542	966	1508	101657	168047
1382	27800	14	27793	14	10	39	109	158	583	1207	1790	97123	131767
1383	37793	14	27793	14	10	45	141	196	1082	2200	3282	135605	168910
1384	-	-	-	-	-	69	109	178	1450	1857	3307	-	-

Annexture 1 contd... Cell No. 13 STW-82 H Village - Dhanjaiya

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1365	40800	16	40800	16	1	17	170	188	854	942	1796	77494	12733
1366	40800	16	41800	16	12	15	97	124	225	330	555	76538	97697
1367	41200	16	41200	15	21	58	210	289	479	873	1352	84504	52234
1368	41800	16	41200	16	21	45	196	262	599	909	1508	83309	11197
1369	41200	16	41200	17	38	38	165	241	616	648	1344	74173	11208
1370	41200	16	40200	20	23	44	215	282	623	1088	1711	76004	11241
1371	37700	17	37700	16	16	57	277	350	562	1734	2296	65902	15762
1372	35400	17	25400	16	20	57	342	419	741	2296	3027	88534	13576
1373	35400	17	27200	16	35	149	314	498	2566	2335	4901	111279	14498
1374	35400	18	35000	18	25	156	358	539	2384	2623	5007	23825	11622
1375	35000	15	36000	16	20	53	352	425	1405	2111	3576	111344	10458
1376	34600	[illegible]	31110	15	20	136	255	411	2694	3690	6384	128920	15789
1377	24200	18	31800	16	15	54	205	274	1514	2202	3716	-	-
1378	31800	16	31800	16	11	42	202	256	606	2025	2631	104239	20283
1379	31800	16	31800	16	17	40	216	255	1435	1456	2891	84050	17357
1380	31800	16	31800	16	10	59	200	269	713	1385	2098	103567	19335
1381	31800	16	31800	16	10	24	124	158	713	1385	2098	101009	10472
1382	31800	16	31800	16	7	29	119	155	500	1878	2378	157159	17282
1383	31403	16	24600	16	5	49	152	206	830	2305	3135	132175	16815
1384	-	-	-	-	-	47	112	159	899	2192	3091	-	-

Annexture 1 contd...Cell No. 30 STW- 139 H Village - Soron I

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1375	-	-	12000	61	-	-	7	7	-	57	57	61200	-
1376	13500	61	13500	61	14	14	78	106	1264	1102	2366	99148	12640
1377	15120	61	15120	61	11	3	82	96	644	1149	1793	95455	13910
1378	15400	61	17800	25	5	4	67	76	258	1727	1884	128000	14158
1379	13800	66	13800	48	4	44	59	107	211	986	1197	138000	13280
1380	48200	34	48200	30	3	15	142	160	239	811	1050	-	62164
1381	48200	30	48200	30	6	4[illegible]	115	139	138	766	904	70823	11679
1382	45600	31	45600	24	8	4	188	200	371	1293	1669	117672	14108
1383	43230	23	41500	24	9	47	134	190	315	1325	1690	198166	-
1384	-	-	-	-	-	53	136	189	1054	1564	2618	-	-

Note: Fasali Year 1363= 1955-56 ; 1364 = 1956-57; 1365= 1957-58; 1366=1958-59; 1367=1959-60; 1368= 1960-61; 1369= 1961-62 ; 1370= 1962-63 ; 1371=1963-64; 1372=164-65; 1373= 1965-66; 1374= 1966-67 ; 1375= 1967-68 ; 1376= 1968-69; 1377=1969-70; 1378= 1970-71; 1379= 1971-72 ; 1380= 1972-73 ; 1381= 1973-74; 1382= 1974-75 1383= 1975-76; 1384= 1976-77, and 1385 = 1977-78, Financial year, which commence from 1st April and end on 31st March of next year. Fasli year Kharif started from 1st April of the year and end on 30th September of the same year and Fasli year Rabi started from 1st October and end on 31st Mar. as the financial year.

TABLE 9

MEAN AVERAGE DISCHARGE AND RUNNING HOURS FOR KHARIF FASAL (1363 to 1384) FOR THE STWS' OF HANDIA TEHSIL

S.No.	Fasali year of running of STWS'	No. of STWS' energised during the year	MEAN AVERAGE DISCHARGE AND RUNNING HOURS IN TIME INTERVAL PERIODS											
			1363-67		1368-72		1373-77		1378-80		1381-82		1383-84	
			Qm	Hm	Qm	Hm	Qm	Hm	Qm	Hm	Qm	Hm	Qm	Hm
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1363	5	29435	216	33000	446	29404	1761	30555	620	29700	498	27180	925
2	1364	5	30239	216	31414	630	24532	1820	27434	590	24364	467	22438	631
3	1365	56	33564	276	35109	596	27006	1741	26250	848	25274	585	24784	707
4	1366	11	39750	395	23560	781	24545	1581	24428	807	22384	451	22143	750
5	1367	0	39750	395	23560	781	24545	1581	24428	807	22384	451	22143	750
6	1368	4	-	-	35456	973	31193	2139	29915	529	29215	476	25463	712
7	1369	9	-	-	37200	1057	32618	1903	29562	958	21274	576	24400	844
8	1370	0	-	-	37200	1057	32618	1903	29562	958	21274	576	24400	844
9	1371	15	-	-	24550	418	24886	1513	24130	364	25463	608	26040	630
10	1372	0	-	-	24550	418	24886	1513	24130	364	25463	608	26040	630
11	1373	2	-	-	-	-	21935	1416	26099	584	26485	401	25800	600
12	1374	19	-	-	-	-	32606	916	29202	570	29600	377	29610	785
13	1375	15	-	-	-	-	26749	1060	25800	585	27238	458	32261	701
14	1376	15	-	-	-	-	37502	877	32138	815	27135	503	31100	877
15	1377	11	-	-	-	-	34000	455	33053	324	32466	708	30467	770
16	1378	16	-	-	-	-	-	-	32546	209	31167	351	26665	720
17	1379	25	-	-	-	-	-	-	32180	497	29757	431	27998	566

Table 9 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
18	1380	19	-	-	-	-	-	-	43900	190	44900	531	42653	718
19	1381	23	-	-	-	-	-	-	-	-	43672	447	43672	575
20	1382	30	-	-	-	-	-	-	-	-	37070	53	34533	648
21	1383	8	-	-	-	-	-	-	-	-	-	-	32455	876
22	1384	0	-	-	-	-	-	-	-	-	-	-	32455	876

Qm = mean average discharge in gallons per hour

Hm = mean average running hours

Total pumpage during Kharif Fasal for the STWS' energised during a particular year was calculated by multiplying total no. of STWS' (column 3) and mean average discharge and running hours for a particular time interval (shown in column from 4 to 15) of the year. Similar calculations were done for pumpage due to other STWS' which were energised earlier, but were running during the particular year, under consideration. Adding both pumpages total draft or pumpage for Kharif fasal of the particular year was computed.

Similar calculations were computed for Rabi Fasal. Adding Kharif and Rabi pumpages, total pumpage of the particular year under consideration(in gallons) was calculated. Later on it was changed in metric units. Some model calculations regarding mean average discharge and running hours for Kharif Fasal are given in Table 10.

TABLE 10

MODEL CALCULATIONS FOR AVERAGE AND MEAN AVERAGE, DISCHARGE AND RUNNING HOURS OF SOME STWS' OF STUDY AREA

Mean Av. Qm and Hm for the STWS' of Year (1957-53)

No. and Group of STW	FOR THE TIME INTERVAL 1363 to 1367		1368 to 1372		1373 to 1372		1378 to 1380		1381to 1382		1383 to 138	
	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
1	2	3	4	5	6	7	8	9	10	11	12	13
KHARIF-FASAL (CROP)												
33 H	29700	315	33200	1099	33726	2259	32875	1249	29713	563	27793	1266
77 H	30033	488	34860	993	27646	2662	33071	1127	36105	718	31814	556
79 H	35400	330	35400	687	27428	2347	27700	1105	24200	544	24200	927
81 H	36300	343	37900	599	34920	2146	32483	1237	31800	862	31800	1095
82 H	40533	519	37700	628	33410	2113	31800	918	31300	606	27840	865
Mean Average	34393 Qm	399 Hm	35812 Qm	301 Hm	31426 Qm	2305 Hm	31587 Qm	1127 Hm	30734 Qm	659 Hm	28689 Qm	942 Hm

Q = Average discharge in gallons per hour
Qm = Mean average discharge in gallons per hour
Hm = Mean average running hours

VARIOUS DATA OF STATE TUBE-WELLS OF HANDIA TEHSIL

No. S.T.W. No. and Group	Year of constru-ction or year of enerrgisa-tion	Original			Present (1976-77)1384F			Prop. Irrig-able Comma-nd Area Acres	Details of pipe Assembly		
		Discharge in GPH	Depre-ssion in Ft.	Spring Level in Ft.	Disch-arge in GPH	Depre-ssion in Ft.	Spring Level in Ft.		Hous-ing Pipe Ft.	Slotted Pipe Ft.	Blind Pipe Ft.
2	3	4	5	6	7	8	9	10	11	12	13
1 H	1957	31800	14	37	32000	14	48	520	92	145	72
2 H	1957	31800	16	38	22000	16	50	435	92	188	172
3 H	1955	31300	19	44	24000	13	55	325	92	152	165
4 H	1955	31300	14	42	24000	13	53	482	92	163	102
5 H	1955	30000	18	44	24000	13	55	550	98	153	197
6 H	1955	30000	10	42	14600	13	60	650	91	215	171
7 H	1957	24400	18	54	10000	10	58	425	101	86	17
8 H	1955	24000	13	42	20000	12	60	404	107	174	93
9 H	1956	24000	18	51	24000	14	60	497	110	73	66
10 H	1956	29100	20	48	14000	11	60	442	110	111	66
11 H	1957	26200	18	50	22000	14	60	400	108	65	71
12 H	1957	24400	12	54	24000	14	60	405	111	66	62
13 H	1957	24400	12	44	25000	17	58	557	101	157	119
14 H	1958	23200	20	38	24080	16	57	411	101	169	99
15 H	1957	23200	19	35	24080	16	57	400	101	146	123
16 H	1957	26200	16	30	17622	18	58	285	81	100	292
17 H	1957	27200	16	30	26283	17	58	275	82	159	187
18 H	1967	31000	12	55	22000	14	58	450	81	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
19	19 H	1958	31100	11	35	22373	10	57	450	91	108	256
20	20 H	1358	29100	16	40	23300	14	51	582	91	75	294
21	21 H	1961	31100	19	58	31314	16	52	500	94	95	75
22	22 H	1958	25300	20	49	12300	12	50	344	90	60	–
23	23 H	1957	21900	20	30	20942	12	50	635	99	142	259
24	24 H	1961	33200	12	27	28000	12	54	373	82	105	100
25	25 H	1957	29100	20	44	20442	16	58	357	92	62	150
26	26 H	1961	33200	17	33	16182	10	59	285	82	–	–
27	27 H	1958	34300	9	30	34800	11	55	575	92	124	127
28	28 H	1957	33400	22	26	25900	10	50	300	91	135	226
29	29 H	1957	35400	12	25	24030	16	49	567	90	175	198
30	30 H	1957	32200	20	26	20942	10	58	510	91	175	229
31	31 H	1957	34300	10	20	14832	16	58	330	91	279	48
32	32 H	1357	36200	15	22	27790	14	52	632	90	123	168
33	33 H	1958	33200	17	20	27790	14	52	714	90	116	109
34	34 H	1957	41200	10	19	24080	12	54	300	92	111	46
35	35 H	1957	36500	9	23	20942	12	–	353	32	78	42
36	36 H	1957	31100	17	20	26400	12	49	760	93	128	24
37	37 H	1957	35400	18	20	31150	16	–	509	82	90	106
38	38 H	1958	35400	17	20	23370	12	40	384	82	107	169
39	39 H	1958	40000	19	25	42600	16	52	777	83	104	141
40	40 H	1957	32100	19	25	22000	14	50	465	91	107	160

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
63	63 H	1957	36200	18	20	21150	8	48	634	79	109	143
64	64 H	1961	33234	15	35	32500	15	45	500	121	133	20
65	65 H	1958	35400	18	22	22800	13	51	510	101	98	80
66	66 H	1957	36200	14	18	28370	15	50	340	-	-	-
67	67 H	1957	36200	16	18	28670	15	50	340	-	-	-
68	68 H	1957	27200	15	28	21100	10	53	586	83	95	202
69	69 H	1957	36200	17	26	27400	12	54	400	-	-	-
70	70 H	1958	20300	38	35	66600	25	52	264	99	65	148
71	71 H	1961	37700	15	40	28380	16	47	535	88	98	216
72	72 H	1961	30367	13	47	21532	9	56	616	-	-	-
73	73 H	1957	36200	15	20	32400	22	51	568	81	109	153
74	74 H	1961	31000	16	39	20400	12	59	420	114	135	17
75	75 H	1957	27200	15	38	66600	12	59	625	82	86	146
76	76 H	1957	37700	21	30	31840	17	69	407	81	98	124
77	77 H	1957	26400	20	27	14832	10	64	404	81	111	117
78	78 H	1957	32100	20	25	24609	13	64	400	92	108	197
79	79 H	1958	35400	20	30	26438	12	61	349	92	112	123
80	80 H	1957	37700	20	25	19600	12	60	488	82	68	188
81	81 H	1957	36200	20	24	24600	12	47	521	81	78	104
82	82 H	1957	40800	16	18	24600	14	53	337	115	146	40

1	2	3	4	5	6	7	8	9	10	11	12	13
83	83 H	1957	37700	18	33	21157	14	47	588	80	82	53
84	84 H	1958	37700	16	23	18112	12	50	795	83	82	54
85	85 H	1958	33200	18	18	18162	12	50	300	80	–	–
86	86 H	1962	35400	13	22	26438	18	40	460	96	109	40
87	87 H	1963	33540	13	54	27793	16	60	663	115	108	73
88	88 H	1958	16000	17	25	21152	22	49	424	–	–	–
89	89 H	1958	36655	10	36	22373	10	55	411	101	98	51
90	90 H	1963	35400	18	15	24373	8	48	345	115	133	57
91	91 H	1957	36500	16	32	29000	13	53	312	94	97	93
92	92 H	1957	34000	16	32	25000	13	53	500	91	123	68
93	93 H	1963	33200	13	50	17000	11	46	345	113	149	13
94	94 H	1963	33200	18	30	20300	12	44	465	115	108	14
95	95 H	1963	27100	35	20	22373	18	41	435	–	–	–
96	96 H	1964	14500	14	20	10400	18	51	464	75	99	92
97	97 H	1964	31100	13	22	16600	12	49	526	–	–	–
98	98 H	1963	33400	19	20	24080	11	60	375	85	141	104
99	99 H	1963	27100	24	40	20000	12	56	420	100	95	138
100	100 H	1963	27100	20	40	26438	13	51	496	90	50	25
101	101 H	1964	24720	20	40	20200	12	56	617	–	–	–

Annexture 2 contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
102	102 H	1963	24200	20	42	21108	10	48	500	-	-	-
103	103 H	1964	31100	10	30	40200	17	35	300	-	-	-
104	104 H	1964	20300	17	28	24200	17	35	300	93	90	183
105	105 H	1963	31100	18	28	22000	15	55	400	-	-	-
106	106 H	1965	15700	13	50	26000	14	52	471	-	-	-
107	107 H	1965	25200	12	49	24000	13	53	502	-	-	-
108	108 H	1966	27200	17	58	20000	12	59	350	-	-	-
109	109 H	1966	20300	16	62	22000	12	64	410	125	120	25
110	110 H	1966	20300	5	64	27793	7	58	485	117	83	6
111	111 H	1966	23000	6	62	30764	11	63	353	92	112	94
112	112 H	1966	27200	16	39	20400	13	58	445	80	128	77
113	113 H	1966	31161	15	47	20000	14	58	425	86	120	37
114	114 H	1966	31800	15	40	23000	12	53	445	78	120	67
115	115 H	1967	22590	15	45	24000	13	52	492	78	132	61
116	116 H	1967	22000	14	44	18000	12	57	500	88	107	95
117	117 H	1967	32400	18	45	16000	17	58	620	90	106	87
118	118 H	1967	31800	16	35	20942	8	52	600	92	101	18
119	119 H	1967	31800	16	34	21152	13	45	600	96	148	19

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
120	120 H	1967	23649	13	41	24609	16	61	545	-	-	-
121	121 H	1967	33234	12	37	21150	17	47	460	-	-	-
122	122 H	1966	27200	14	37	21150	14	46	500	-	-	-
123	123 H	1966	31300	16	34	18300	12	45	507	-	-	-
124	124 H	1966	27200	13	52	28300	14	32	375	-	-	-
125	125 H	1966	20300	15	34	18100	16	42	492	-	-	-
126	126 H	1966	27200	17	34	26438	15	40	450	78	103	127
127	127 H	1966	20300	17	40	19600	15	45	455	-	-	-
128	128 H	1966	27200	14	42	21152	13	47	400	-	-	-
129	129 H	1967	27840	20	22	27400	22	46	500	97	109	112
130	130 H	1967	15100	21	23	26400	22	40	500	102	115	104
131	131 H	1967	30000	16	28	18100	20	45	505	-	-	-
132	132 H	1967	20300	12	45	24609	10	51	541	-	-	-
133	133 H	1967	24200	12	35	15300	13	52	588	95	96	91
134	134 H	1967	24200	17	35	21100	14	49	500	-	-	-
135	135 H	1967	36200	15	25	24600	18	45	527	104	104	97
136	136 H	1967	26100	15	35	24600	10	44	517	105	114	60
137	137 H	1967	31400	20	38	16675	9	45	515	-	-	-
138	138 H	1967	29820	15	35	24600	12	51	405	104	41	33
139	139 H	1967	12000	47	21	36600	20	41	518	111	124	73
140	140 H	1967	36000	13	52	18000	12	58	424	145	141	127

Annexture 2 contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
141	141 H	1968	20348	40	50	26000	13	60	350	146	82	161
142	142 H	1968	36000	17	38	32000	16	65	380	-	-	-
143	143 H	1970	33780	15	54	42675	15	56	403	139	144	24
144	144 H	1970	40800	15	36	26000	15	55	403	-	-	-
145	145 H	1970	36200	12	50	27404	14	45	350	115	143	40
146	146 H	1968	36200	18	48	28371	14	48	496	105	143	12
147	147 H	1968	33780	16	36	27404	12	50	405	-	-	-
148	148 H	1968	32820	14	47	21152	11	49	360	115	128	21
149	149 H	1968	36315	12	42	25000	12	69	380	120	150	[illegible].5
150	150 H	1968	36000	13	43	22000	12	58	315	106	120	40
151	151 H	1969	41500	15	35	26438	14	45	370	119	140	67
152	152 H	1969	28400	16	40	24080	9	55	500	-	-	-
153	153 H	1968	26200	15	52	18112	12	49	425	118	137	108
154	154 H	1968	35100	16	47	18112	12	55	400	116	140	19
155	155 H	1968	36200	13	47	20300	14	43	425	115	88	14
156	156 H	1968	36200	12	44	21152	12	47	552	117	110	63
157	157 H	1969	31800	15	43	25000	18	55	370	126	110	66
158	158 H	1970	36450	13	38	34000	13	52	415	120	86	74
159	159 H	1969	33780	15	46	12373	10	47	400	122	147	65
160	160 H	1969	32400	13	42	21150	18	50	382	112	142	24
161	161 H	1969	40870	15	44	31814	13	53	450	113	120	23

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
162	162 H	1969	37700	13	43	28370	66	47	453	-	-	-
163	163 H	1969	31800	15	46	26438	13	49	450	135	145	26
164	164 H	1969	36200	15	36	28371	13	59	400	120	160	50
165	165 H	1969	36200	14	42	27404	12	45	360	-	-	-
166	166 H	1969	32400	20	40	22860	10	54	380	133	133	91
167	167 H	1969	36000	22	41	28300	11	53	367	-	-	-
168	168 H	1971	27200	9	28	28300	18	42	493	-	-	-
169	169 H	1971	51000	16	46	45800	17	52	552	121	143	94
170	170 H	1971	62500	30	32	36000	20	38	682	116	122	82
171	171 H	1971	53950	30	34	45800	20	47	780	118	123	98
172	172 H	1971	45600	30	36	24600	21	42	556	110	118	79
173	173 H	1970	26500	15	42	24600	10	48	416	128	132	59
174	174 H	1971	27800	12	42	14832	10	56	500	101	61	58
175	175 H	1970	28371	14	42	12317	9	63	300	108	114	118
176	176 H	1970	26400	13	43	20800	12	63	470	125	103	142
177	177 H	1970	41540	14	42	27000	12	58	390	121	128	42
178	178 H	1970	45900	32	57	24000	14	64	495	130	125	100
179	179 H	1970	24180	15	58	20000	13	58	515	121	177	87
180	180 H	1970	30850	15	52	18000	14	60	425	-	-	-
181	181 H	1970	31800	15	44	24000	12	58	340	-	-	-

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
182	182 H	1970	30000	10	44	22600	13	56	350	-	-	-
183	183 H	1970	31803	15	45	20400	12	57	460	-	-	-
184	184 H	1970	36200	13	54	27793	11	62	334	125	138	90
185	185 H	1971	40000	9	36	29600	12	46	350	135	250	25
186	186 H	1971	43340	11	38	29354	14	50	350	-	-	-
187	187 H	1971	40300	20	54	27793	12	58	520	121	137	10
188	188 H	1971	45900	11	40	33000	12	58	400	-	-	-
189	189 H	1971	27840	20	42	30764	18	55	343	-	-	-
190	190 H	1971	27800	15	51	22373	8	60	520	-	-	-
191	191 H	1970	45000	20	60	28730	15	59	315	-	-	-
192	192 H	1970	36813	17	43	31814	10	56	515	-	-	-
193	193 H	1971	45000	25	43	32814	15	65	475	-	-	-
194	194 H	1971	45000	23	61	40000	16	61	420	-	-	-
195	195 H	1971	28371	12	35	27793	14	66	425	-	-	-
196	196 H	1971	36800	20	44	32870	13	58	349	-	-	-
197	197 H	1971	45000	15	44	33940	14	55	305	135	130	85
198	198 H	1971	45000	14	42	25000	15	42	410	-	-	-
199	199 H	1971	48000	14	44	27793	13	56	360	-	-	-
200	200 H	1971	45000	14	42	31814	15	60	410	-	-	-
201	201 H	1971	18300	10	65	18000	13	60	755	-	-	-

Annexture 2 contd.....

1	2	3	4	5	6	7	8	9	10	11	12	13
202	202 H	1971	36200	13	39	28371	15	50	510	130	100	40
203	203 H	1972	45600	15	30	51000	15	46	745	-	-	-
204	204 H	1973	40000	15	54	26000	14	64	350	-	-	-
205	205 H	1973	48000	28	45	21000	15	57	483	-	-	-
206	206 H	1973	354000	15	33	32500	13	41	378	-	-	-
207	207 H	1972	55900	14	40	21100	13	41	452	-	-	-
208	208 H	1972	21200	50	30	41500	18	48	405	120	150	242
209	209 H	1972	50500	26	31	41500	18	47	452	-	-	-
210	210 H	1972	29350	15	35	24600	16	42	450	-	-	-
211	211 H	1972	51000	25	29	45800	19	44	460	-	-	-
212	212 H	1972	20850	14	38	22860	12	45	407	-	-	-
213	213 H	1971	62500	20	35	30360	12	49	441	116	159	186
214	214 H	1972	30400	18	33	31800	15	40	416	-	-	-
215	215 H	1972	51000	17	45	41540	13	45	469	-	-	-
216	216 H	1973	15300	27	47	16670	23	52	500	-	-	-
217	217 H	1972	31800	22	32	19300	30	50	465	-	-	-
218	218 H	1972	56000	20	40	36600	21	48	467	-	-	-
219	219 H	1972	20850	18	60	24080	10	68	425	127	92	39
220	220 H	1973	41504	20	36	15300	7	46	400	-	-	-
221	221 H	1973	27840	20	30	15100	7	69	420	-	-	-

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
221	221 H	1973	36000	20	30	15100	7	69	420	-	-	-
222	222 H	1973	36000	10	60	17622	8	60	300	-	-	-
223	223 H	1973	48600	13	40	24000	16	56	300	-	-	-
224	224 H	1973	35400	14	38	19600	13	51	800	-	-	-
225	225 H	1973	50000	15	50	40000	15	63	375	-	-	-
226	226 H	1973	21600	15	43	21532	15	53	405	-	-	-
227	227 H	1973	27350	15	32	31000	14	51	403	-	-	-
228	228 H	1973	29820	14	40	22860	15	47	410	-	-	-
229	229 H	1972	51000	18	37	31000	17	52	400	-	-	-
230	230 H	1973	38300	14	30	36800	14	46	430	121	160	70
231	231 H	1973	31200	18	41	37000	19	49	450	-	-	-
232	232 H	1973	41504	20	36	41540	18	47	474	-	-	-
233	233 H	1973	45000	15	40	32000	13	57	415	108	125	47
234	234 H	1973	42000	13	40	22000	14	50	405	-	-	-
235	235 H	1973	45600	20	55	24080	9	58	401	-	-	-
236	236 H	1974	55000	23	33	51000	16	49	465	-	-	-
237	237 H	1974	30360	12	45	22860	10	52	400	-	-	-
238	238 H	1973	45600	25	34	41540	18	45	500	-	-	-
239	239 H	1973	27404	15	30	21100	12	52	540	-	-	-

Annexture 2 contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
240	240 H	1973	35000	14	56	36000	13	52	405	-	-	-
241	241 H	1973	51000	14	40	36500	14	52	440	-	-	-
242	242 H	1973	46300	15	42	30000	15	56	400	-	-	-
243	243 H	1973	36200	15	51	40660	14	62	288	-	-	-
244	244 H	1973	45600	20	55	31814	17	60	362	130	115	15
245	245 H	1973	45600	35	30	24600	16	42	450	-	-	-
246	246 H	1974	24609	20	25	26600	20	48	495	-	-	-
247	247 H	1973	40800	22	31	39100	20	48	503	-	-	-
248	248 H	1973	40800	25	45	20000	12	62	400	-	-	-
249	249 H	1973	46000	22	37	32429	15	47	540	-	-	-
250	250 H	1973	31800	20	31	27400	12	48	423	-	-	-
251	251 H	1974	26000	13	60	25000	13	60	410	-	-	-
252	252 H	1974	45900	18	48	35034	13	54	370	-	-	-
253	253 H	1974	36200	17	39	28380	15	47	492	-	-	-
254	254 H	1974	36000	14	58	36000	14	56	440	-	-	-
255	255 H	1974	42400	17	40	28371	18	48	450	-	-	-
256	256 H	1974	24200	14	50	36800	14	65	364	-	-	-
257	257 H	1974	36160	16	44	20962	10	60	382	-	-	-
258	258 H	1974	17622	18	48	40860	13	58	375	-	-	-

Annexture 2 contd....

1	2	3	4	5	6	7	8	9	10	11	12	13
259	259 H	1974	24609	12	48	27793	11	67	555	120	120	84
260	260 H	1974	30000	13	54	30000	14	61	410	-	-	-
261	261 H	1974	28000	14	55	14000	18	60	525	-	-	-
262	262 H	1974	22820	12	48	22863	14	50	499	-	-	-
263	263 H	1974	30764	14	65	30000	16	62	372	-	-	-
264	264 H	1974	40339	18	46	36160	16	58	400	-	-	-
265	265 H	1974	10000	13	60	17000	14	58	405	-	-	-
266	266 H	1974	31800	23	32	36600	16	44	400	120	170	88
267	267 H	1975	36000	15	65	36000	15	64	360	-	-	-
268	268 H	1974	36160	16	42	20942	11	60	488	-	-	-
269	269 H	1974	38500	13	40	26823	9	58	300	-	-	-
270	270 H	1975	27200	30	30	21150	15	55	403	-	-	-
271	271 H	1974	31800	12	38	31800	16	49	360	-	-	-
272	272 H	1974	36000	15	65	20000	14	60	410	-	-	-
273	273 H	1975	28730	14	50	31814	12	63	463	-	-	-
274	274 H	1975	18112	20	40	24600	15	52	545	-	-	-
275	275 H	1976	30764	8	55	24080	9	44	384	-	-	-
276	276 H	1974	24609	12	53	33940	17	68	465	-	-	-

Annexture 2 contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
277	277 H	1975	36200	22	30	23800	24	43	370	110	130	78
278	278 H	1974	36160	20	44	20942	11	59	450	-	-	-
279	279 H	1974	30000	14	58	20000	16	60	450	-	-	-
280	280 H	1975	44000	15	62	24000	15	60	350	-	-	-
281	281 H	1974	27000	15	60	29000	15	58	300	-	-	-
282	282 H	1974	36000	15	60	24000	15	58	451	-	-	-
283	283 H	1975	25000	16	60	14832	16	60	350	-	-	-
284	284 H	1975	24080	16	55	14332	12	68	420	-	-	-
285	285 H	1974	14000	12	51	24000	13	58	300	-	-	-
286	286 H	1975	36600	12	42	20942	10	57	370	-	-	-
287	287 H	1975	30360	14	46	28570	9	50	400	-	-	-
288	288 H	1975	30360	15	45	32400	7	52	537	-	-	-

1. (-) Means data are not available
2. These data are as per list provided by the Tube-Well Division II, Allahabad. Hence for accuracy, before using these data it should be compared with original one of the state tube-wells, of Handia Tehsil.

MODIFIED COMPUTER PROGRAMME REGARDING
THE STATE TUBE-WELLS OF HANDIA TEHSIL


```
C*****************************************************************************
C     THE FOLLOWING PROGRAM IS ADAPTED FROM THE AQUIFER SIMULATOIN
C
C     PROGRAM DEVELOPED BY PRICKETT AND LONNQUIST
C*****************************************************************************
C     HO(I,J)------ HEADS AT START OF TIME INCREMENT (FT.)
C     H(I,J) ------ HEADS AT END OF TIME INCREMENT (FT)
C     SF1(I,J) ------ STORAGE FACTOR FOR ARTESIAN CONDITIONS (GAL/FT)
C     STORAGE FACTOR IS DEFINED AS SF1 = 7.48.S. X. Y.  WHERE S IS STOR
C     COEFFICIENT,  X AND  Y ARE GRID SPACINGS.
C     Q(I,J) ------ CONSTANT WITHDRAWL RATES (GPD)
C      T(I,J,1) ------ AQUIFER TRANSMISSIBILITY BETWEEN (I,J) AND (I,J+1
C     (GAL/DAY/FT)
C     T(I,J,2) ------ AQUIFER TRANSMISSIBILITY BETWEEN (I,J) AND (I+1,J)
C     IN GAL/DAY/FT
C     AA,BB,CC,DD ------ COEFFICIENTS IN WATER BALANCE EQUATIONS
C     NR ------ NUMBER OF ROWS IN MODEL
C     NC ------ NUMBER OF COLUMNS IN MODEL
C     NSTEPS -- NUMBER OF TIME INCREMENTS
C     DELTA -- TIME INCREMENT (DAYS)
C     HH,S1,QQ,TT ---- DEFAULT VALUES
C     I ------ MODEL COLUMN NUMBER
C     J ------ MODEL ROW NUMBER
C     BOTH S1 AND SF1(I,J) STAND FOR STORAGE FACTOR
C
      DIMENSION H(50,50),HO(50,50),SF1(50,50),Q(50,50),
     1T(50,50,2),B(50),G(50),DL(50,50)
C
C     TURN OFF UNDER FLOW TRAP
C
      CALL FLUN(3200 )
      INTEGER OUT
      IN = 5
      OUT = 6
C
C     READ PARAMETER CARD AND DEFAULT VALUE CARD
C
      READ (IN,10) NSTEPS,ERROR,NC,NR,TT,S1,HH,QQ
   10 FORMAT (I6,E12.5/2I6,4E12.3)
C
C     PRINT PARAMETER AND DEFAULT VALUES
C
      WRITE (OUT,15) NSTEPS,ERROR,NC,NR,TT,S1,HH,QQ
   15 FORMAT (I6,E15.8,2I6,4E15.8)
C
C     FILL ARRYS WITH DEFAULT VALUES
C
      DO 20 I=1,NC
      DO 20 J=1,NR
      T(I,J,1) = TT
```

```
      T(I,J,2) = TT
      SF1(I,J) = SS
      H(I,J) = HH
      HC(I,J) = HH
    2 G(I,J) = GG
C
C     READ NODE CARDS
C
      INDEX=0
   21 READ 22,DELTA
      READ 22,TT2,SS2,HH2,GG2
   22 FORMAT (4E15.8)
      IF (TT2.EQ.999.0) GO TO 332
      PRINT 22,TT2,SS2,HH2,GG2
      DO 24 I=4,20
      DO 24 J=4,20
      T(I,J,1) = TT2
      T(I,J,2) = TT2
      SF1(I,J) = SS2
      H(I,J) = HH2
      HC(I,J) = HH2
   24 G(I,J) = GG2
      DO 26 I=1,23
      J=21
      T(I,J,1)=TT2/2.0
      T(I,J,2)=TT2/2.0
      SF1(I,J)=0.1*(10.0**22)
      H(I,J)=0.
      HC(I,J)=0.
      G(I,J)=0.
   26 CONTINUE
   30 READ (IN,41) I,J,T(I,J,1),T(I,J,2),SF1(I,J),H(I,J),G(I,J)
   41 FORMAT (2I6,5E12.5)
      IF (I.GT.NC) GO TO 50
C
C     PRINT NODE VALUES
C
      WRITE (OUT,42) I,J,T(I,J,1),T(I,J,2),SF1(I,J),H(I,J),G(I,J)
   42 FORMAT (2I6,5E15.8)
      GO TO 30
C
C     START OF SIMULATION
C
   50 TIME =0.
      DO 220 ISTEP=1,NSTEPS
      TIME = TIME+DELTA

      IF (DELTA.EQ.30.) GO TO 52
      IF (DELTA.EQ.40.) GO TO 52
      GO TO 53
```

```
52 DO 54 I=4,20
   DO 54 J=5,15,2
   Q(I,J) = -QQ2
54 CONTINUE
   GO TO 57
53 DO 55 I=4,20
   DO 55 J=5,15,2
   Q(I,J) = QQ2
55 CONTINUE
57 CONTINUE
C
C     PREDICT HEADS FOR NEXT TIME INCREMENT
C
   DO 70 I=1,NC
   DO 70 J=1,NR
   D = H(I,J)-HO(I,J)
   HO(I,J) = H(I,J)
   F = 1.0
   IF (DL(I,J).EQ.0.) GO TO 60
   IF (ISTEP.GT.2)  F=D/DL(I,J)
   IF (F.GT.5.0) F=5.
   IF (F.LT.0.0) F=0.0
60 DL(I,J) = D
70 H(I,J) = H(I,J)+D*F
C
C     REFINE ESTIMATE OF HEADS BY IADI METHOD
C
   ITER = 0
80 E = 0.0
   ITER = ITER+1
C
C     COLUMN CALCULATIONS
C
   DO 190 II=1,NC
   I=II
   IF (MOD(ISTEP+ITER,2).EQ.1) I=NC-I+1
   DO 1[illegible] J=1,NR
C
C     CALCULATE B AND G ARRAYS
C
   BB = SF1(I,J)/DELTA
   DD = HO(I,J)*SF1(I,J)/DELTA-Q(I,J)
   AA = 0.0
   CC = 0.0
   IF (J-1) 90,100,90
90 AA = -T(I,J-1,1)
   BB = BB+T(I,J-1,1)
100 IF (J-NR) 110,120,110
110 CC = -T(I,J,1)
   BB = BB+T(I,J,1)
```

```
   12  IF (I-1) 130,140,130
   130 BB = BB+T(I-1,J,2)
       CC = CC+H(I-1,J)*T(I-1,J,2)
   140 IF (I-NC) 150,160,150
   150 BB = BB+T(I,J,2)
       CC = CC+H(I+1,J)*T(I,J,2)
   160 W = BB-AA*B(J-1)
       B(J) = CC/W
   17  G(J) = (CC-AA*G(J-1))/W
C
C      RE-ESTIMATE HEADS
C
       E = E+ABS(H(I,NR)-G(NR))
       H(I,NR = G(NR)
       N = NR-1
   18  HA = G(N)-B(N)*H(I,N+1)
       E = E+ABS(HA-H(I,N))
       H(I,N) = HA
       N = N-1
       IF (N) 191,190,180
   190 CONTINUE
C
C      ROW CALCULATIONS
C
       DO 300 JJ=1,NR
       J = JJ
       IF (MOD(ISTEP+ITER,2)).EQ.1) J=NR-J+1
       DO 290 I=1,NC
       BB = SF2(I,J)/DELTA
       CC = HC(I,J)*SF1(I,J)/DELTA-Q(I,J)
       AA = 0.
       CC = 0.
       IF (J-1) 200,210,200
   200 BB = BB+T(I,J-Y,1)
       CC = CC+H(I,J-1)*T(I,J-1,1)
   21  IF (J-NR) 220,230,$220
   22  CC = CC+H(I,J+1)*T(I,J,1)
       BB = BB+T(I,J(1)
   23  IF (I-1) 1
   23  IF (I-1) 240,250,240
   240 BB = BB+T(I-1,J,2)
       AA = -T(I-1,J,2)
   250 IF (I-NC) 260,270,260
   260 BB = BB+T(I,J,2)
       CC = -T(I,J,2)
   270 W = BB-AA*B(I-1)
       B(I) = CC/W
   280 G(I) = (CC-AA*G(I-1))/W
C
C
```

```
C
C     RE-ESTIMATE HEADS
C
      E = E+ABS(H(NC,J)-G(NC))
      H(NC,J) = G(NC)
      N = NC-1
 29   HA = G(N)-B(N)*H(N+1,J)
      E = E+ABS(H(N,J)-HA)
      H(N,J) = HA
      N = N-1
      IF (N) 30,30,29
 30   CONTINUE
      IF (E.GT.ERROR) GO TO 90
C
C     PRINT RESULTS
C
      WRITE (OUT,310) TIME,E,ITER
 31   FORMAT (1X,* TIME = *,E15.8-///,E20.7,I5)
      IF (INDEX.EQ.1) DELTA=DELTA*2.7
      IF (INDEX.EQ.1) DELTA=DELTA*3.2
      DO 32  J,1,NR
 32   WRITE (OUT,330) J,(H(I,J),I=1,NC)
 33   FORMAT (I5,5X,10F10.4/(12X,10F10.4))
      INDEX = INDEX+1
      GO TO 21
 331  STOP
      END
```

ANNEXTURE 4

NEWS AND VIEWS REGARDING WORKING OF STATE TUBE-WELLS DURING PERIOD OF POSTING OF THE AUTHOR AT HANDIATEHSIL

भारत

में वह अपने एक रिश्तेदार के साथ गांव चौकी से निकला आ रहा था। गांव के बाहर पांच युवकों के एक गिरोह ने उन पर अचानक हमला किया और रिश्तेदार की लाठियों से पिटाई की और उसे भी खदेड़ा। पीटे गये व्यक्ति को बेहोशी की हालत में गांव वाले घर ले गए और उपचारार्थ देशी अस्पताल में भरती करा दिया गया। इसकी रिपोर्ट थाना मेजा में दर्ज की गई है।

प्रसार कार्य का निरीक्षण

गत १७ अप्रैल को स्थानीय श्री राजप्रताप इंटर कालेज में कृषि एवं प्रसार कार्य का निरीक्षण जिला विद्यालय निरीक्षक श्री सीताराम सिंह ने किया और संतोष व्यक्त किया।

नगरपालिका की बैठक

(निज संवाददाता द्वारा)

मऊरानीपुर (झांसी), २२ अप्रैल। अरसे की अवधि समाप्त होने के बाद नगरपालिका की पहली बैठक हुई। श्री हीरालाल सुरेलिया सदस्य का सभापति चुना गया। बैठक में ट्रैक्टर की मरम्मत के लिए ६२०० रु. स्वीकृत किया गया। तयाबी का ठेका स्वीकृत किया गया। बैठक में वरिष्ठ उपाध्यक्ष एवं कनिष्ठ उपाध्यक्ष के चुनाव की मांग की गई। तब तक परगनाधीश श्री एम. हरित बोर्ड के चेयरमैन रहेंगे।

दुकानदार गिरफ्तार

ज्ञात हुआ है कि निर्धारित मूल्य से अधिक मूल्य पर वनस्पति बेचने के कारण आरोप में पुलिस ने एक दुकानदार को गिरफ्तार किया।

हंडिया नलकूप उपखंड का कीर्तिमान

(निज संवाददाता द्वारा)

हंडिया (इलाहाबाद), २२ अप्रैल। हंडिया नलकूप उपखंड ने अपने संचालकों की कार्यकुशलता एवं प्रशासनिक अधिकारियों की दक्षता के फलस्वरूप सम्पूर्ण उत्तर प्रदेश के नलकूप उपखंडों की तुलना में सर्वाधिक कीर्तिमान स्थापित किया।

हंडिया तहसील के 'कृषक समाज' ने अपनी सभा में कु. प्रवीण चन्द्र सिंह, अधिशासी अभियन्ता, नलकूप खंड, इलाहाबाद एवं श्री आर. एल. सिंह, सहायक अभियन्ता, नलकूप उपखंड हंडिया, इलाहाबाद का अभिनन्दन किया और कहा कि १९५९ के बाद नलकूप प्रशासन में जो अभिवृद्धि हुई उससे क्षेत्र की जनता का अपार सुख प्राप्त हुआ।

हंडिया नलकूप उपखंड ७७ नलकूप मशीन गत वर्ष ७९०० घंटों में लगभग चलकर और ११० एकड़ क्षेत्र सिंचित करके समस्त उ. प्र. में अपना कीर्तिमान स्थापित किया। साथ ही इस उपखंड में लगभग ६००० घंटे या इससे अधिक चलने वाले नलकूपों की संख्या लगभग ३४ रही। लगभग ६ नलकूप ऐसे थे जो लगभग ७००० घंटे चले।

श्री आर. एल. सिंह, सहायक अभियन्ता के संचालन में गत वर्ष ४८५३१ एकड़ भूमि की सिंचाई इन नलकूपों द्वारा हुई व इस उपखंड में अनवरत ३ 'टेस्ट बोरों' कार्यरत हैं।

द्वारा ... एडवोकेट, राम प्रताप सिंह, मुकुन्द सिंह लोगों ने भी अपनी राय ... उनके द्वारा ... किये जाने पर ... तथा अनुरोध किये ... प्रदेश में ... में पूरा ... में अवकाश भी ... के संचालक होने ...

''अंधं वलं जलं च आहु
प्रणेतव्यं विचक्षणैः ''
-महाभारत

'WATER IS A MORE BLIND FORCE - THOUGH TREMENDOUS. IT HAS TO BE GUIDED BY PROPER DISCRIMINATION.'

MAHABHARAT

'THERE IS NOTHING IN THE WORLD MORE SOFT AND WEAK THAN WATER, YET FOR ATTACKING THINGS THAT ARE HARD AND STRONG THERE IS NOTHING THAT SURPASSES IT, NOTHING THAT CAN TAKE ITS PLACE'.

LAO TSE,
6th Century, B.C.